CONSERVATION VOLTAGE REDUCTION TRIAL

City of Lethbridge Electric Utility

Abstract

This report summarizes the implementation / function / and trial results of applying an Advanced Metering Infrastructure enabled Conservation Voltage Reduction technology known as DVI EDGE. The pilot project was completed by a partnership formed between the City of Lethbridge Electric Utility (LEU), Alberta Innovates, and Dominion Voltage Incorporated (DVI). The pilot project was the first initiative moved forward with input and assistance from the Alberta Smart Grid Consortium

The pilot project was performed between January 2018 and March 2019 and the DVI EDGE system was responsible for regulating the voltage delivered to 10 000 customers within the LEU distribution system. The trial demonstrated that DVI EDGE can reliably and safely reduce distribution system operating voltage within approved CSA standards. The reduction in voltage was successful in creating energy conservation savings and greenhouse gas reductions for all customers while requiring no behavioral change.

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Disclaimer

List of Abbreviations

AESO – Alberta Electric System Operator

AMI – Advanced Metering Infrastructure

CSA – Canadian Standards Association

CVR – Conservation Voltage Reduction

DFO – Distribution Facility Operator

DVI – Dominion Voltage Incorporated

DVR – Demand Voltage Reduction

EDGE – Energy Distribution Grid Efficiency (DVI software)

EPRI – Electrical Power Research Institute

GHG – Green House Gas

GIS – Geographic Information Systems

LEU – Lethbridge Electric Utility

MW – Mega Watt (power or demand)

MWh – Mega Watt-hour (energy or consumption)

OLTC – On-Load Tap Changer

SCADA – Supervisory Control and Data Acquisition

Executive Summary

In 2018, Lethbridge became the first community in Western Canada to introduce new, smart grid technology aimed at improving the energy efficiency of its electric distribution grid that delivers power to customers throughout the city.

Lethbridge Electric Utility (LEU) partnered with Alberta Innovates and Dominion Voltage Inc. (DVI) on a pilot project to implement DVI's Conservation Voltage Reduction (CVR) technology, EDGE CVR, at one of the city's six electric substations. The purpose of the pilot project was to demonstration that the EDGE CVR system, using data from LEU's Advanced Metering Infrastructure (AMI), can safely lower the operating voltage of the electric distribution system while ensuring that electricity continues to be delivered to all customers well within national standards set by the Canadian Standards Association (CSA). The outcome of the project would be validation of the technical, environmental, and economic benefits that result from the deployment of the EDGE CVR system.

The LEU pilot demonstrated that with the EDGE CVR system operating the voltage level, MW demand, and MWhs of consumption were reduced compared to operating the distribution system using traditional voltage regulation schemes. This pilot project confirmed small energy savings for individual customers added up to a significant reduction in overall power consumption and demand for the community's electric system. The efficiency gain and resulting energy savings were possible without the need for residential, commercial and institutional customers to change their behavior. The pilot project technical, economic, and environmental benefits are shown in Table 1 below.

Table ES1 – Pilot Results Summary for operations between April 1, 2018 – January 31, 2019

Pilot Reporting Goal	**Description**	**Results**
Technical	Average Voltage Reduction Total Energy Savings	1.14 % 554 MWh
Economic	Energy Savings to customers at 6.8 cents / kWh	$37,687
Environmental	Green House Gas Reduction	380 tonnesCO_2e

It should be noted that reported energy savings and GHG emission reductions in Table 1 are less than the potential of the EDGE CVR system because:

- The EDGE CVR system was turned on and off during the pilot project in order to complete the necessary testing and data collection to be able to thoroughly test the EDGE CVR system; and
- LEU did not attempt to maximize voltage reductions using EDGE CVR during the pilot. LEU did not want to reduce voltage on the distribution system to the lower half of approved CSA band until the functionality of the EDGE CVR system and its impact on customer meter points was better understood.

The goal of determining that EDGE CVR would run reliably and safely lower the operating voltage on the distribution system was validated and LEU will continue to lower the operating voltage of the distribution system to gain greater savings and GHG reductions for customers. LEU is confident that efficiency improvement targets between 2% and 4% are achievable with the long term operation of EDGE CVR.

Table 1 above represents the key performance metrics that were defined for the LEU pilot project. It is also important to note that other important benefits were also realized from the deployment of the EDGE CVR system. These additional benefits include:

- **Expediting the deployment and enhancement of other LEU "smart grid" initiatives.** LEU's existing Geographic Information System (GIS) data is used to map the location and attributes of all electric utility assets. In order to deploy the EDGE CVR system, it was necessary to "clean up" GIS data to provide a corrected connectivity model from the GIS. This "clean up" work is also required for the implementation of the Outage Management System (OMS) functionality that is now also deployed by LEU. The OMS enables LEU to respond to customer outages in a more efficient manner. OMS leverages the information available from the integration of GIS, AMI, and SCADA data which is then analyzed by the OMS algorithms. The outputs of the OMS algorithms provide a predictive tool for distribution system operators to find and repair system failures when they occur.
- **Optimizing LEU's distribution system infrastructure to enable further CVR voltage reductions and identify and prioritize future capital upgrading projects.** DVI's

EDGE CVR system includes a functionality called EDGE Planner. EDGE Planner's voltage diagnostic tools have provided the LEU Distribution Engineering group visibility into the voltage performance on the connected load. The analysis performed through EDGE Planner has allowed the LEU Distribution Engineering group to correct high and low voltage outlier locations by adjusting localized transformer output levels within the distribution network, modifying primary feeder connectivity by strategic network switching, and identifying areas with overall lower voltages during distribution system load peaking conditions which will be considered for capital upgrading priority in future years.

- **Data management and optimization training for LEU staff.** Learning opportunities were provided to LEU data systems staff to integrate the activities of the GIS, SCADA, AMI, and now CVR data base systems on both operational and corporate networks in a secure and efficient manner. Leveraging the combined expertise of DVI and LEU, assisted in the deployment of the EDGE CVR system and has better prepared LEU for future work in the "smart grid" space.
- **Knowledge dissemination to Alberta Distribution Facility Owners.** Many dedicated hours were put into this pilot by the staff of LEU and DVI with positive outcomes for both entities and this created a positive outcome for all participants within the Alberta Smart Grid Consortium. This was the first project being supported through the Alberta Smart Grid Consortium, which consists of Alberta Innovates, Alberta Energy, and the Alberta Distribution Facility Owners (DFOs) ATCO, ENMAX, EPCOR, FortisAlberta, Alberta Federation of Rural Electrification Associations (AFREA), EQUS, and Cities of Lethbridge, Red Deer and Medicine Hat. LEU led the project and worked in partnership with DVI to deploy and demonstrate their EDGE CVR system. The other members of the Consortium were participants as project committee members and have access to the results and learnings from this project. The success of the collaboration was evident by the strong attendance at the final workshop to share learnings, held at LEU's operational facility in Lethbridge on February 26, 2019.

The next step for this pilot project is to investigate the opportunity for full deployment across LEU's entire distribution system. With full implementation in 2019-2021, LEU expects to achieve energy savings of up to 33,600 megawatt hours (MWh) of electricity annually – the equivalent of removing 4,400 homes from the grid.

Introduction

Electricity System Background

Electricity is delivered from generation sources to customers throughout Alberta via transmission and distribution networks. Two key variables used to describe how these systems are utilized and in turn billed for cost recovery are “demand” and “consumption”.

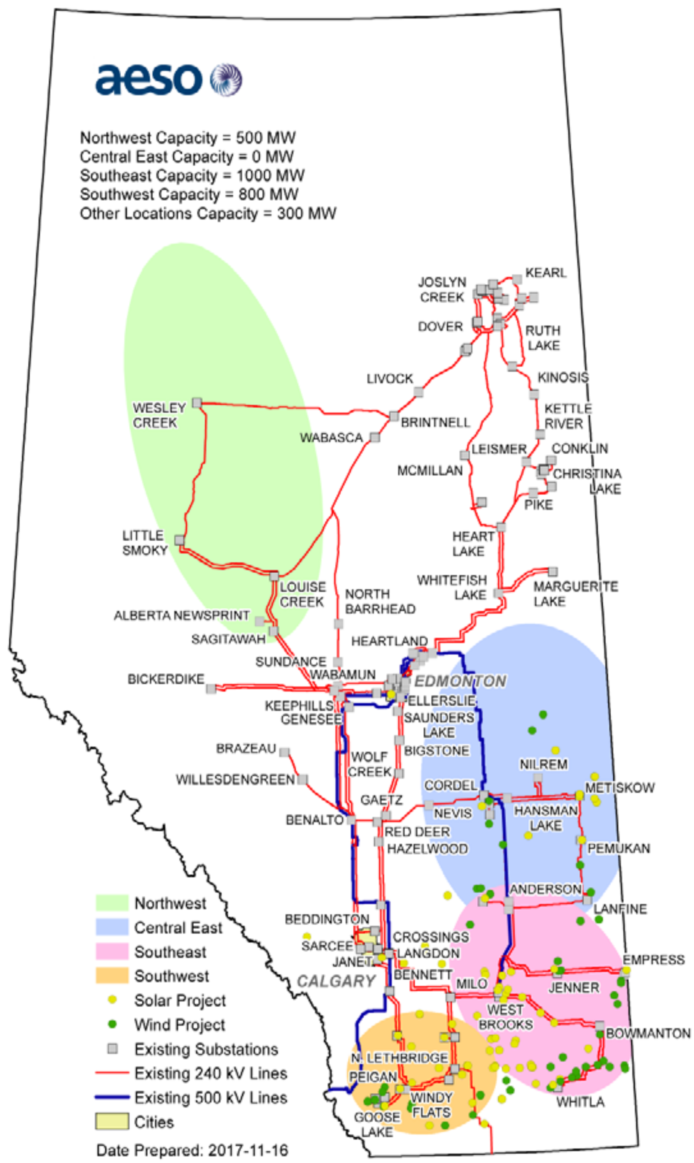
Electrical demand is the measurement of the relative “instantaneous” requirement for electrical energy that a connected load creates. For example a 100 W light bulb creates an electrical demand of 100 W when it is connected. Because of the vast amount of load connected to any distribution or transmission network, demand is normally reported in MW.

Electrical consumption is the measure of how much energy is used by a customer and is simply the electrical demand multiplied by the amount of time that demand is connected to the system. For example if the 100 W light bulb is connected for 1 hour then the consumption would be recorded as 100 Wh. Again, because of the vast amount of consumption that occurs on distribution and transmission networks consumption is normally reported in MWh.

Transmission facilities are generally defined as the network that ships large “bulk” amounts of electrical energy long distances at high voltage, typically between 69 000 V to 500 000 V. Transmission facilities exist throughout the province and they also make electrical connections to adjacent provinces and states. Transmission facilities in Alberta are owned and operated by multiple Transmission Facility Owners (TFO). The responsibility for planning, operating, and setting rates for the transmission system reside with a province wide administrator known as the Alberta Electric System Operator (AESO). Figure 1 shows the Provincial Transmission Network, Figure 2 highlights the Southern Area of the Provincial Transmission Network and Figure 3 illustrates the details of the transmission system in the Lethbridge area.

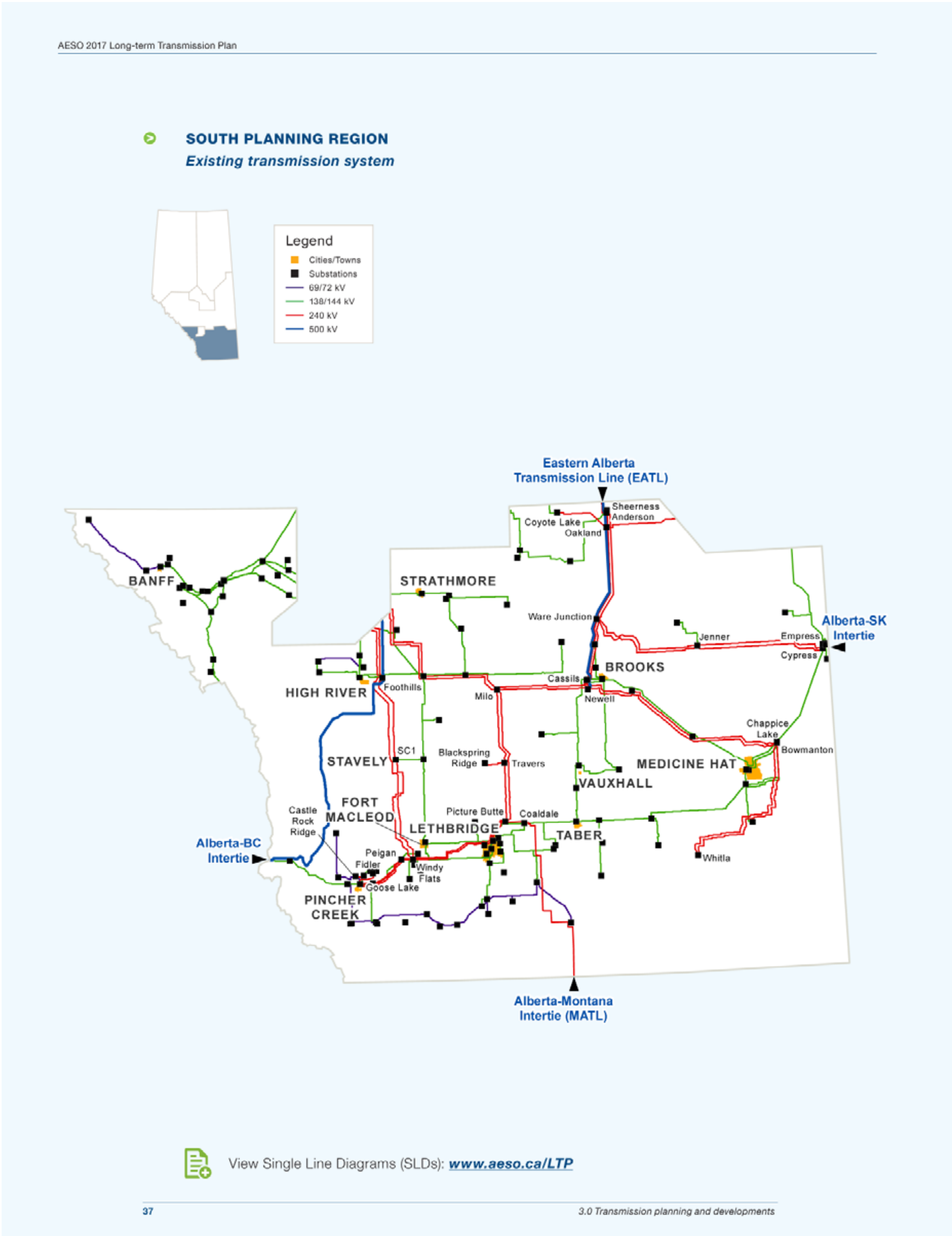
AESO 2017 Long-term Transmission Plan

Figure 3.0-1: Existing transmission system capability and current renewable generation applications



3.0 Transmission planning and developments 26

Figure 1 – AESO Provincial Transmission Network


AESO 2017 Long-term Transmission Plan

SOUTH PLANNING REGION
Existing transmission system

View Single Line Diagrams (SLDs): ***www.aeso.ca/LTP***

37 3.0 Transmission planning and developments

Figure 2 – AESO South Area of Provincial Transmission Network

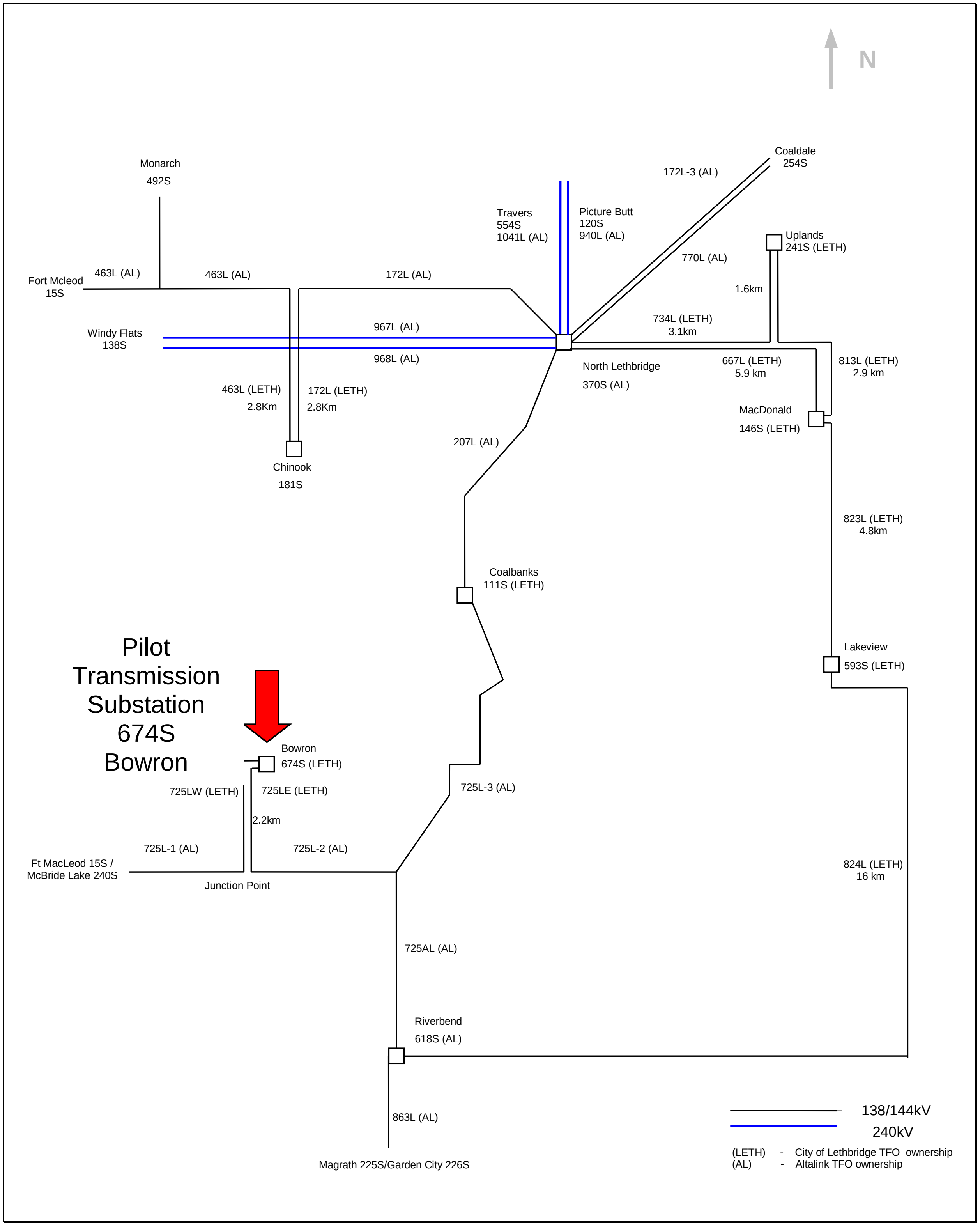


Figure 3 – Lethbridge Area Transmission Network

Distribution facilities are generally defined as the networks that deliver electrical energy from transmission substations to end use customers. Distribution customers are generally categorized as residential, commercial, industrial, and institutional. Distribution facilities typically operate at medium voltage levels ranging from 4000 V to 25 000 V. There are a number of distribution facility owners (DFO) in the province and each DFO has a defined service territory where they are mandated to provide electrical connections for load and distributed generation customers.

There are also large industrial customers in the province who receive their electrical energy directly from the transmission network who are normally referred to as "direct connect" customers. These customers typically own their connection transmission substations and the distribution network that provides electrical energy throughout their facilities on private property.

DFO customers throughout the province receive electrical energy at various voltage levels depending upon their requirements. Customers that are connected via DFO facilities can choose to receive electrical service at standard nominal voltages including:

- 120/240 V typical of residential and small commercial customers
- 120/208V or 347/600 V typical of midsize commercial / industrial / institutional customers
- 4000 V to 25 000 V typical of larger commercial / industrial / institutional customers

For the purposes of this report, a "120 V nominal" voltage will be referred to throughout. "120 V nominal" is the voltage that the majority of electrical users are familiar with. Typical residential electric plug-ins and lighting operate at a nominal or normal voltage of 120 V. In the report "120 V nominal" could be interchanged with 208 V, 600 V, 13 800 V, 25 000 V etc. depending upon the delivery voltage that a customer has chosen to receive at their facility.

As electric energy flows from a transmission substation, through the distribution facilities in route to the customer's meter point, the voltage gradually decreases along the DFO primary feeder lines (see figure 4 below). The customer's meter point is considered the demarcation point between the utilities facilities and the customer's facilities.

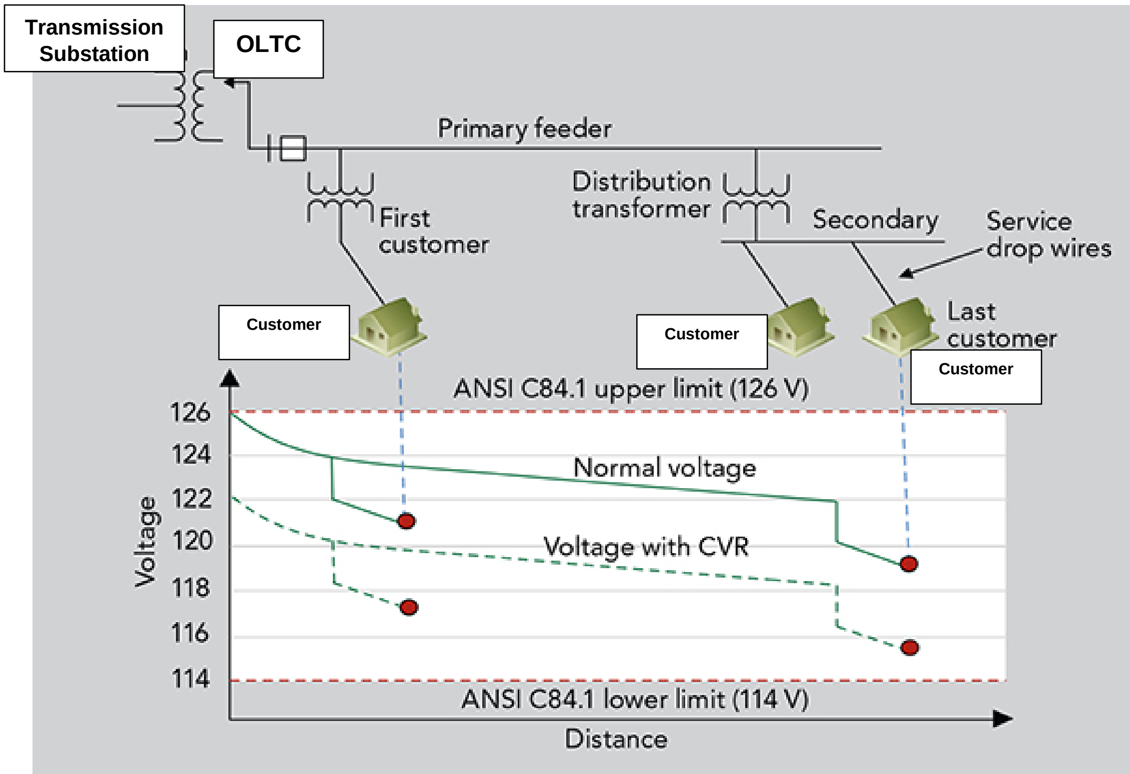


Figure 4 – Typical Primary Feeder layout and Voltage drops

Voltage at the transmission substation that is the source of electrical energy for the DFO primary feeder must be elevated above the nominal delivery value to insure that every customer on the primary feeder receives at least 110 volts while no customer gets more than 125 volts. This band of acceptable voltages is known as the “Canadian Standards Association (CSA) band” between 110-125 volts.

The voltage at the source transmission substation is controlled by the On Line Tap Changer (OLTC). The OLTC provides a regulated or “set voltage” to the DFO primary feeder line.

At any point in time, the voltage that is delivered to the customer’s meter point will vary due to many variables on the utility system. The primary variables that affect the voltage delivered are:

1. The amount of electrical current, often referred to as load, flowing on the primary feeder system required to satisfy the customer electrical loads connected at that time. During times of large connected load to a DFO primary feeder (typically late afternoon / early evening in residential areas) voltage drops between the source substation and the

customer are larger than during times of small connected load (typically between 7pm and 7 am).

2. The electrical characteristic commonly referred to as “resistance” of the DFO primary feeder system. If the wires, switches, and connections are adequately sized and installed for the customer loads, voltage drops along the line will not result in significant voltage drops. Poor quality connections or undersized wire can result in significant voltage drops on the distribution system which will result in non-CSA band voltages being delivered to customers.

If the voltage at a customer’s meter point goes below the CSA band, or below 110 V, they may experience difficulties with electrical loads within their facility. Lights appearing dim, overheating of electrical motors potentially causing tripping, and premature failure of connected electrical devices can all occur when lower than CSA band voltages are provided to customer meter points for significant durations. Due to concerns of providing below CSA band voltages to customers, electric utilities prefer to operate at the higher end of the CSA band. The CSA Band voltages are shown Figure 5.

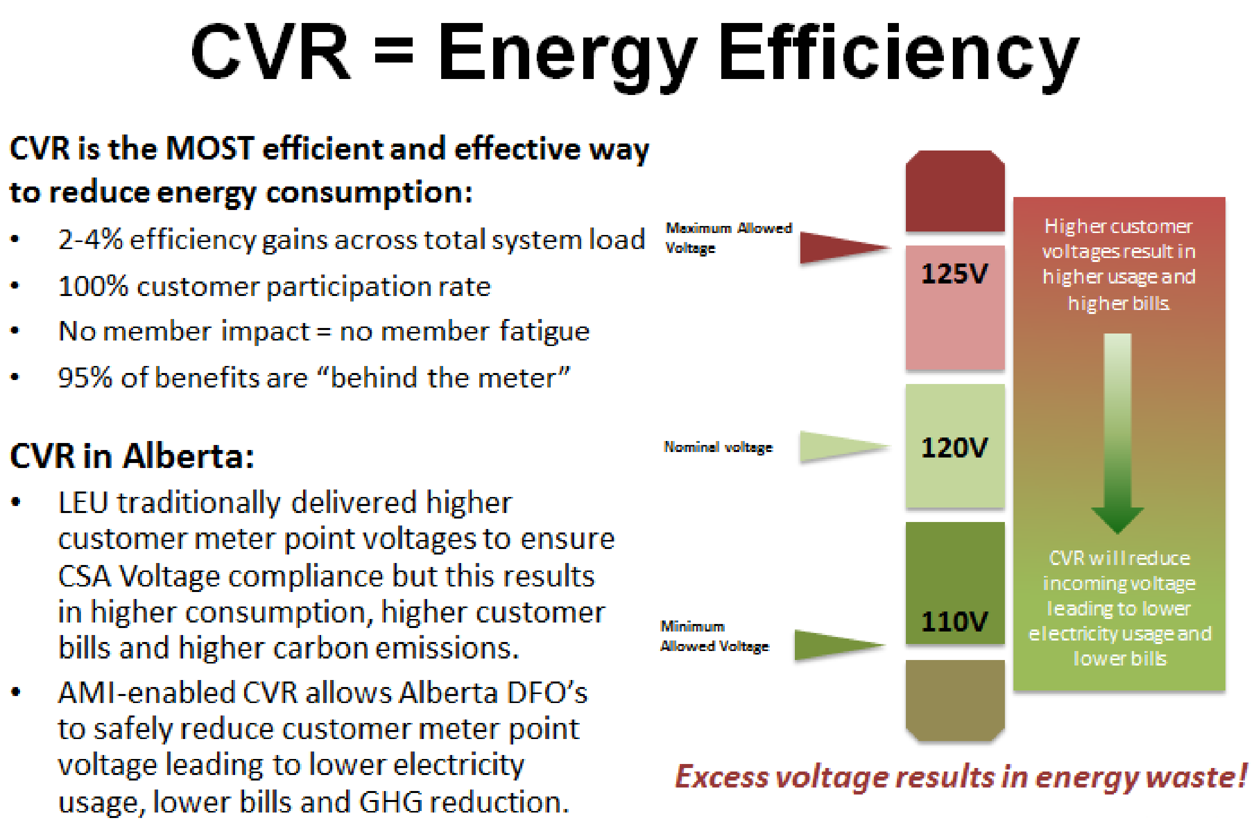


Figure 5 – CSA Band Voltages

Some DFOs have manually lowered the voltage on their primary feeder systems during peak load periods. Peak load periods are normally encountered during late afternoon / early evening periods when total connected electrical load on the DFO primary feeders is reaching a maximum as a result of the concurrent use of the system by all customers: residential, commercial, industrial, and institutional. It has long been known by electric utilities that if the voltage on the primary feeder system is reduced, there is a resulting reduction in the electrical energy required by the connected loads. Therefore, reducing the voltage on the primary feeder system can produce the following benefits for the electric utility and its customers:

1. An economic benefit can be created by lowering bulk electrical supply costs which are created during peak load conditions. The DFO operating the primary feeder system is charged by the AESO for the costs to build and operate the bulk transmission system that supply the DFO through a multi-variable based tariff known as the AESO Demand Transmission Service (DTS) Tariff. The AESO DTS charges are passed through to DFO customers through a distribution tariff which is created by each DFO for its assigned service territory. DTS charges are heavily weighted on the electrical demand, measured in MW, of the DFO during times when the bulk transmission system is experiencing peak load. Bulk system peak load is commonly referred to as “coincident peak”. To a lesser degree the DTS tariff charges for the consumption, measured in MWh, used by the connected DFO customers. It is important to note that DTS charges are levied at each transmission substation where DFO customer load is connected.

2. The reduction in electrical energy required by customers that is created by the reduction in primary feeder voltage can assist the AESO operators in maintaining the required margin between electrical load and supply at critical times of supply shortage due to the temporary loss of a major generation or transmission system elements.

3. The reduction in electrical energy required by the customers that is created by the reduction in primary feeder voltage will reduce their consumption of electricity and therefore the energy portion of their bill will be reduced.

The term associated with the reduction in distribution system demand that results when the voltage is lowered is Demand Voltage Reduction (DVR).

When voltage reduction is performed on a continuous basis (24 hours/day; seven days a week) it is referred to as Conservation Voltage Reduction (CVR). Few utilities have attempted CVR as it was impossible to ensure that CSA band voltages were being delivered consistently to customers due to the variability in conditions that exist on the primary feeder system and a lack of knowledge of customer voltages throughout the distribution system.

However, the advancement and installation of Advanced Metering Infrastructure (AMI) systems at all customer meter points, has enabled enhanced visibility of voltage levels across distribution networks. The AMI data can be leveraged within an AMI-enabled CVR technology system to lower the voltage on distribution primary feeders and realize efficiencies in customer's energy consumption and the overall distribution network peak condition loading, resulting in economic and environmental benefits for all customers.

Project Objectives

In 2011, The City of Lethbridge commissioned the Lethbridge Electric Utility (LEU) to begin implementing an Advanced Metering Infrastructure (AMI) program to all customers including residential, commercial and industrial. LEU is the regulated DFO for the City of Lethbridge and the service area defined for LEU is all customers within the civic boundaries of the City of Lethbridge. In addition, LEU has TFO functionality in the area with ownership of 138 000 V transmission lines and the transmission substations that deliver power from the provincial transmission system to the LEU distribution system (see figure 3).

As the DFO for the City of Lethbridge, LEU is responsible for establishing and maintaining a metering system to all customer meter points. Deploying AMI as the metering solution to meet LEU's requirement was justified on three main principles:

1. To obtain better data on all customer meter points which would provide rate analysts with the ability to more accurately perform cost of service analysis (COSA). COSA is a rigorous method of analyzing and allocating utility operating and capital costs to the broad base of customers served by the utility. As a result of AMI data input to COSA studies done in 2017, LEU made significant adjustments in the rates it charges "standard demand single phase customers" and "standard demand three phase customers" to stop cross subsidization that was occurring between these two classes of LEU customers. (see 2019 LEU Distribution Tariff in Appendix W for further information on rate classes and associated fees)

2. To obtain better data to insure that planning processes and engineering analysis could be supported through analytical techniques in the future. LEU has begun work with an analytics solutions provider, Utilismart, who is assisting LEU in turning the vast amount of data created by the AMI system into better decisions in the placement and replacement of assets across the network.

3. To obtain better data to drive advances in operating efficiencies for all customers. LEU has deployed an Outage Management System (OMS) as part of their SurvalentONE Advanced Distribution Management System (ADMS). The Outage Management Systems leverages AMI, GIS, and SCADA data to assist operators during system outages to direct resources to the assets which need to be isolated and repaired to

return service for customers. In addition the OMS system will provide an outward facing portal which will allow LEU to better communicate information about planned and unplanned outages with their customers.

In addition to the above goals, the deployment of AMI renewed LEU's ageing analog meter assets with new digital technology with all meters capable of sending data to central server data storage via wireless network connectivity. This significant upgrade automated the entire meter reading process.

Figure 6 below is a graphical illustration of the types of customer meter points that LEU's AMI system services.

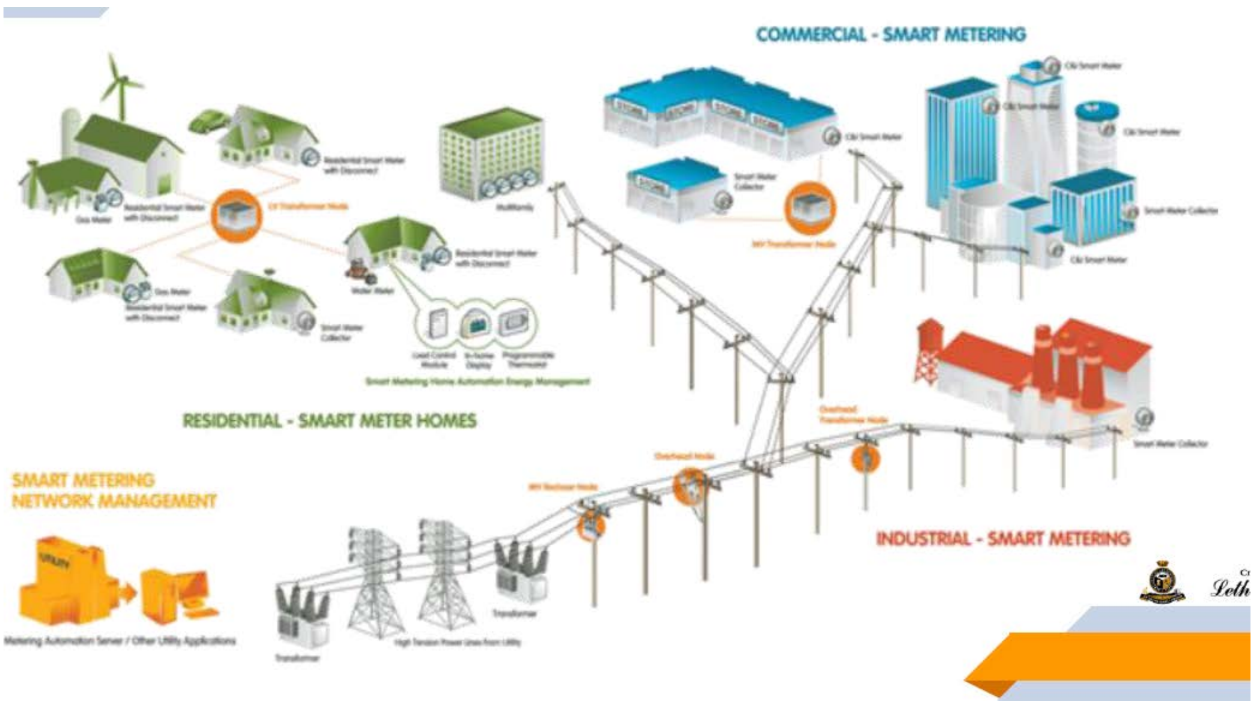


Figure 6 – AMI deployment graphic

In May 2017, the AMI system deployment was completed at all customer locations, or what LEU refers to as customer meter points, and LEU began researching systems that could leverage the AMI data to create efficiency, environmental, and economic gains for their customers.

One of the key initiatives that was identified was the opportunity for Conservation Voltage Reduction (CVR) because the outcome of applying AMI enabled CVR technology is to create 24/7 energy reductions by optimizing the operating voltage of the distribution system. No customer behavior change is required to create the efficiency gain and all connected customers benefit from applying CVR.

LEU learned about AMI enabled CVR while attending the "Distributech" trade show in the fall of 2016 where LEU was introduced to the DVI EDGE CVR product. Follow up visits with DVI sales and technical representatives identified that there was a high level business case for deploying CVR in the LEU system to create efficiency, environmental, and economic gains for customers.

Discussions continued with DVI through spring and summer 2017 and when the Alberta Smart Grid consortium formed in the summer of 2017 with the goal of identifying pilot projects for collaborative learning, LEU put forward the concept of piloting CVR. To date, the deployment of CVR technology using AMI data is still in the early stages and is not broadly adopted in North America, so LEU determined that a pilot project was needed to validate the technical, environmental, analytical and economic effectiveness of a CVR technology using AMI data for input and feedback to the system. The pilot project was approved to move forward to a grant application stage by the Consortium.

In December 2017, the grant application was approved by Alberta Innovates and LEU partnered with Dominion Voltage Incorporated (DVI) and Alberta Innovates to pilot DVI's patented, innovative CVR software technology, called EDGE CVR.

The EDGE CVR system was deployed at one of the six transmission substations in Lethbridge, Bowron 674S. Bowron 674S was selected due to the fact that customers supplied from the substation were mostly residential with one sizeable institutional load. LEU wanted to pilot the CVR functionality on residential type loads as there was a concern that a change in voltage regulation practices might have an impact on more sensitive commercial / industrial loads. Therefore, piloting the functionality on residential load was considered the most prudent option. Close communications with the institutional customer were established prior to the pilot beginning to insure any operational issues were expedited.

Piloting at Bowron 674S placed 10 000 customer meter points under the control of the EDGE CVR system.

Figure 7 illustrates the layout of Bowron 674S substation. In particular, the two On Line Tap Changers (OLTCs) that are controlled by the EDGE CVR system. The OLTCs adjust the distribution system voltage at the transmission system substation. The primary feeder lines connected to the OLTCs which then distribute power to a wide area of the City of Lethbridge shown in Figure 8.

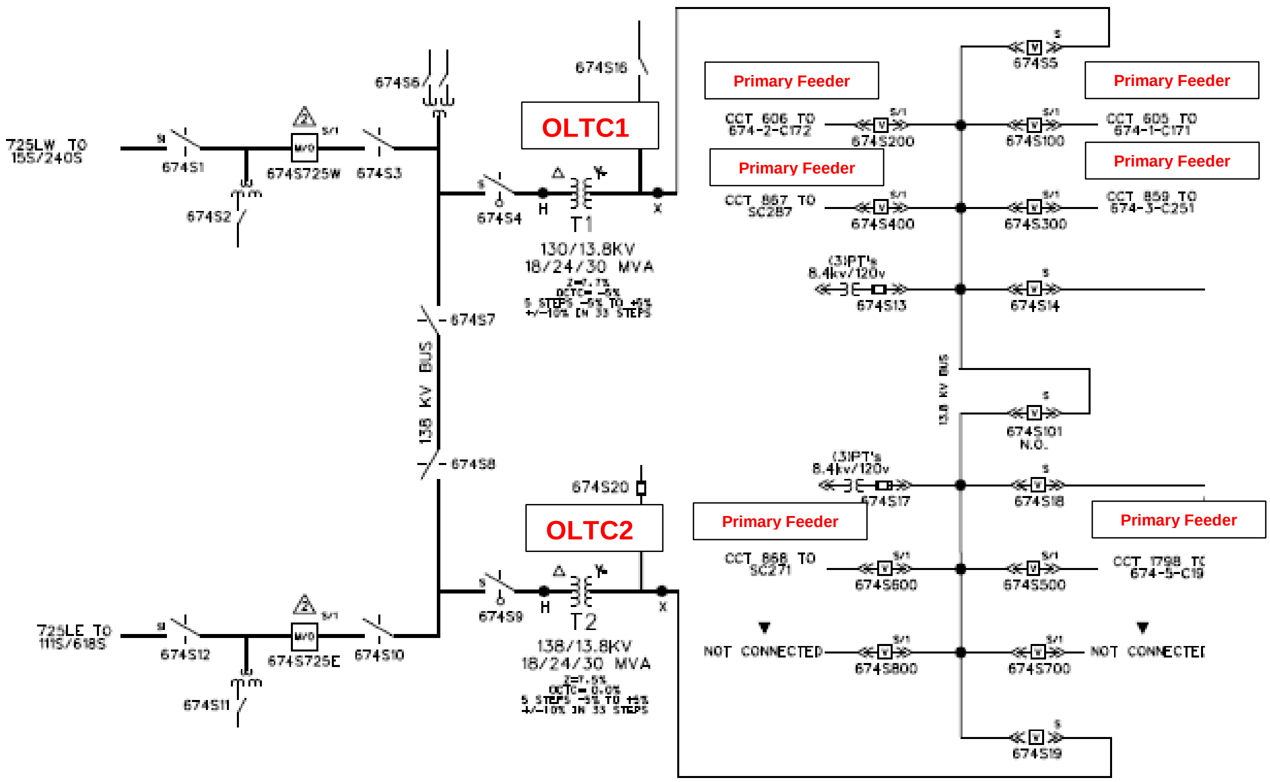


Figure 7 – Bowron 674S Transmission Substation Single Line Diagram

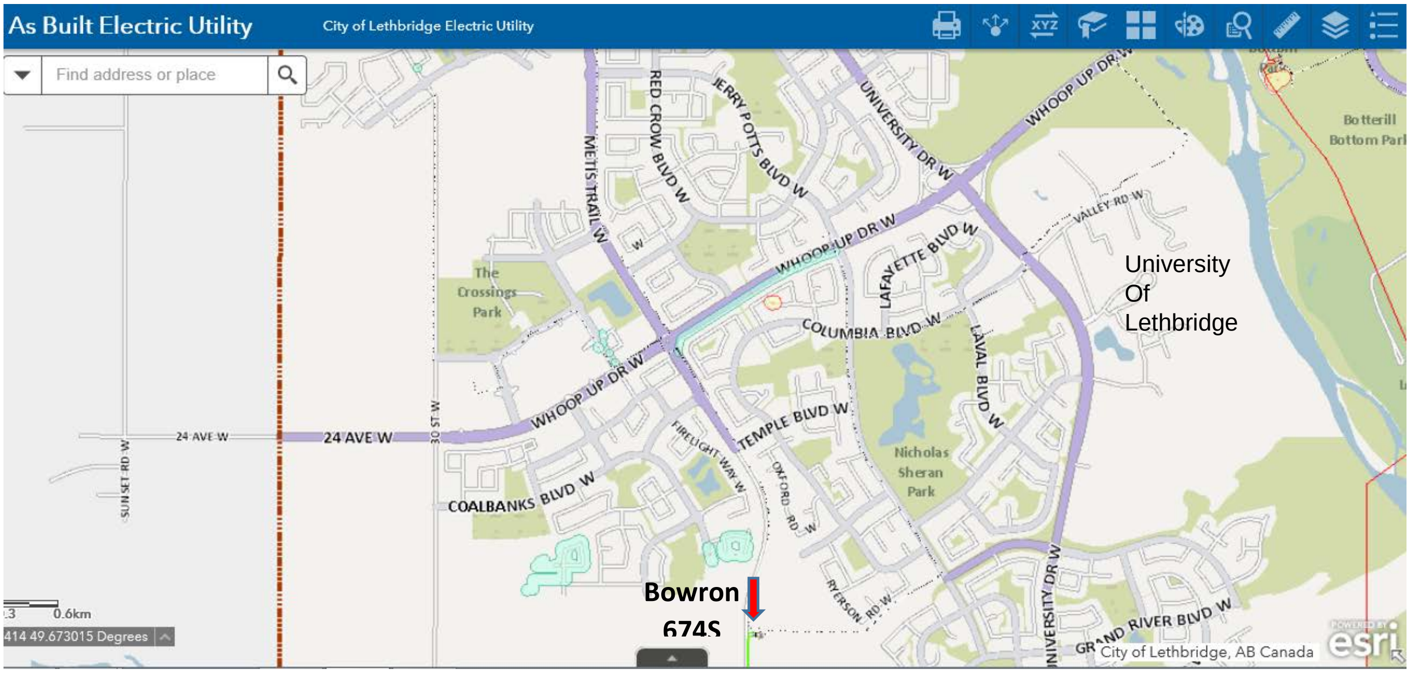


Figure 8 - Map of land area serviced by 674S Bowron

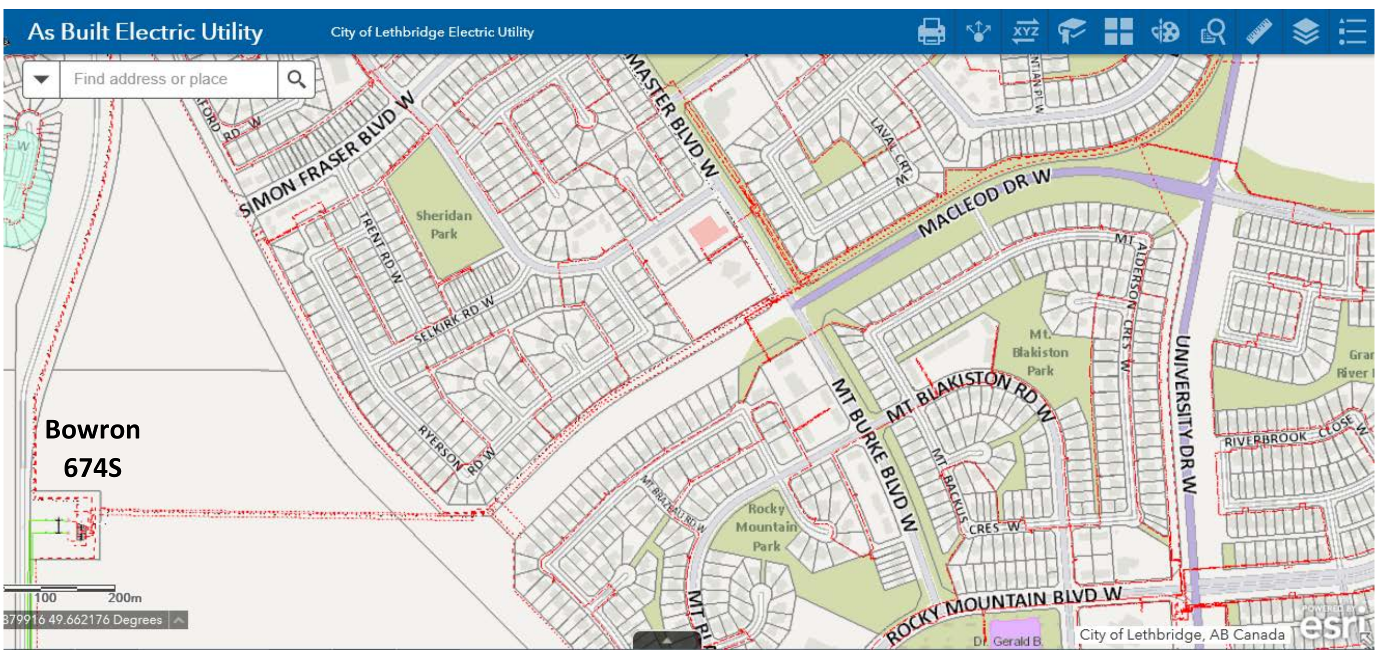


Figure 9– Primary Feeders from 674S Bowron to surrounding civic area

Figure 9 above illustrates how the primary feeder lines (shown as red linework) leave Bowron 674S and travel through road right of ways to enter neighbourhoods to create connectivity paths to customers.

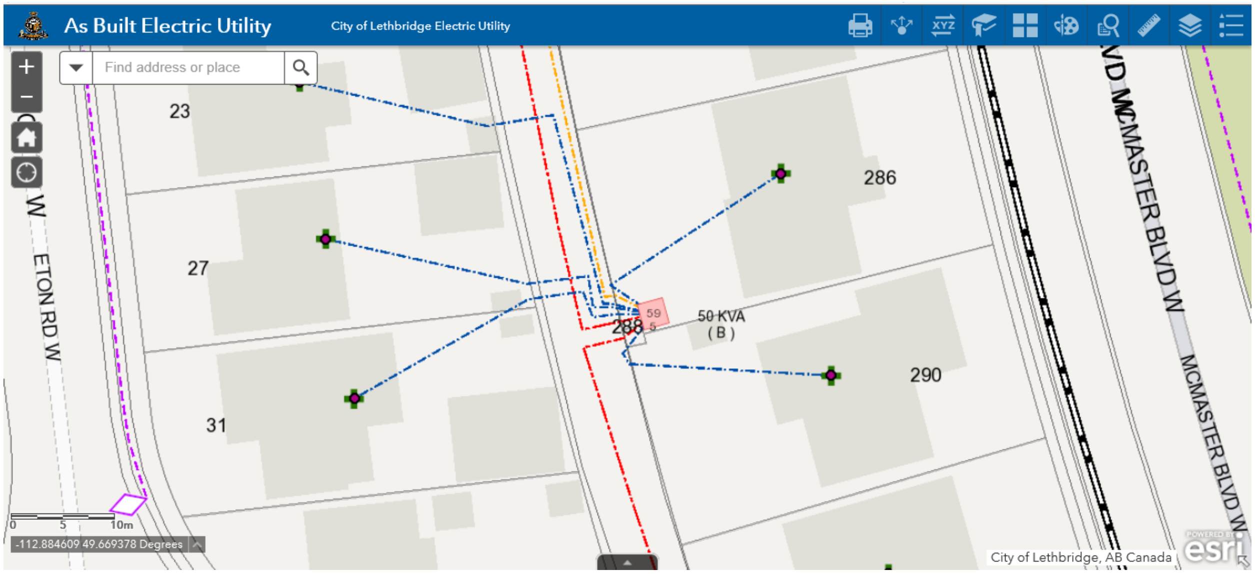


Figure 10 - Primary feed to residential transformer and connection to customer meter points

Figure 10 above shows the detail of creating customer connections between the primary feeder line (shown in red linework) through the distribution system transformer (shown as a pink box) and then the 120 / 240 V connections (shown in blue linework) to the surrounding customer meter points on private residence properties.

The project objectives were to use DVI's EDGE CVR system to optimize LEU's grid operation enabling energy conservation for customers connected to the EDGE CVR controlled substation. The energy conservation would be illustrated through reductions in MWh consumption, MW demand, and greenhouse gas (GHG) emissions which would result in benefits for LEU and all connected customers. In addition to the environmental and economic benefits, DVI's EDGE CVR system would be evaluated on its ability to provide a new level of control and reporting of voltage levels within the LEU distribution system. This smart grid capability will provide a higher level of certainty that customer delivery points are being supplied with CSA band approved voltage levels during all hours of the day throughout the year. This represents a significant improvement in the quality assurance and service that LEU, and all Canadian utilities, can offer to their customers. This is the first AMI-based CVR system deployed in Alberta, indeed in Western Canada, and therefore provides valuable insight into the effectiveness technically, environmentally, and economically of the application in this geographic area.

Methodology

DVI Workshops

Work on the deployment of the DVI EDGE CVR system was initiated in late December, 2017. DVI representatives travelled to Lethbridge to meet with LEU staff and provided a detailed project schedule and deliverables through a workshop on December 19, 2017. This workshop clearly identified roles and responsibilities of team members, both LEU and DVI, and provided a detailed schedule for project activities that would take place between January and March 2018. After this opening work shop work began immediately on the project at LEU

Winter High-Low Studies

The first task of the pilot was to gather the technical data required to determine the winter CVR factor for the two OLTCs at Bowron 674S. Data was captured over a six week period starting January 2, 2018 and ending February 9, 2018.

The CVR factor is what quantifies the ability of the connected electrical loads to reduce the required energy when the applied voltage is reduced. Bowron 674S has two OLTCs that are used to control the voltage on the connected primary feeders. Therefore data was collected from each OLTC to calculate a CVR factor for each OLTC.

In order to obtain the data required to calculate the CVR factor, a high – low study must be performed. The high – low study requires the OLTC to be run at a static high voltage level for one week followed by a static low voltage level for the next week. This high – low cycle is then repeated over a six week trial period.

At LEU, the OLTC settings for a high week were 124.5 V and for a low week were 121.5 V. MW demand and voltage were then recorded on a 15 minute interval basis over the entire 6 week period via the revenue meters on each OLTC. In addition, weather data was collected from a local weather station so that weather data could be correlated with the OLTC MW demand and voltage data.

Weather and OLTC MW demand and voltage data is then run through the EDGE Validator (part of the DVI EDGE CVR system) to analyze the data and calculate the CVR factor. Essentially EDGE Validator is looking for only highly matched pairs of data, one from a high week and one from a low week, where all other variables other than the voltage are static. EDGE Validator is looking to find matched pairs where only the change in voltage is creating a change in the MW demand recorded on the OLTC. The methods of calculating the CVR factor used by EDGE Validator have been reviewed and approved by the Electric Power Research Institute (EPRI) in the US.

Starting Systems Integration

The month of January was spent preparing for DVI Workshop 1 which was scheduled for the week of February 12, 2018. LEU and DVI staff prepared servers, firewall security configurations, and network architectures to support the future installation and operation of the DVI EDGE CVR system.

Within the LEU Electric Distribution Network two different models work largely independently. One model is the Arc GIS system which is used by the Electric Design, Operations and Accounting Groups and the other model is the Survalent ONE SmartVU and Supervisory Control and Data Acquisition (SCADA) Server used by the Control Center Operators to maintain system configuration status. We needed to enable these two systems to communication and interact with each other and also the technical folks on either side to do the same....

DVI EDGE Monitor Mode

During Workshop 1, the week of February 12, DVI technical representatives travelled to Lethbridge to review and clarify all the IT architecture and operating details with LEU staff. The DVI EDGE CVR system was successfully installed onto the LEU servers and the system was turned on in “monitor” mode. In monitor mode the EDGE CVR system begins to communicate with the LEU AMI database and the LEU Supervisory Control and Data Acquisition (SCADA) database to ensure that the IT systems are all communicating correctly. Figure 11 below illustrates the final IT Architecture.

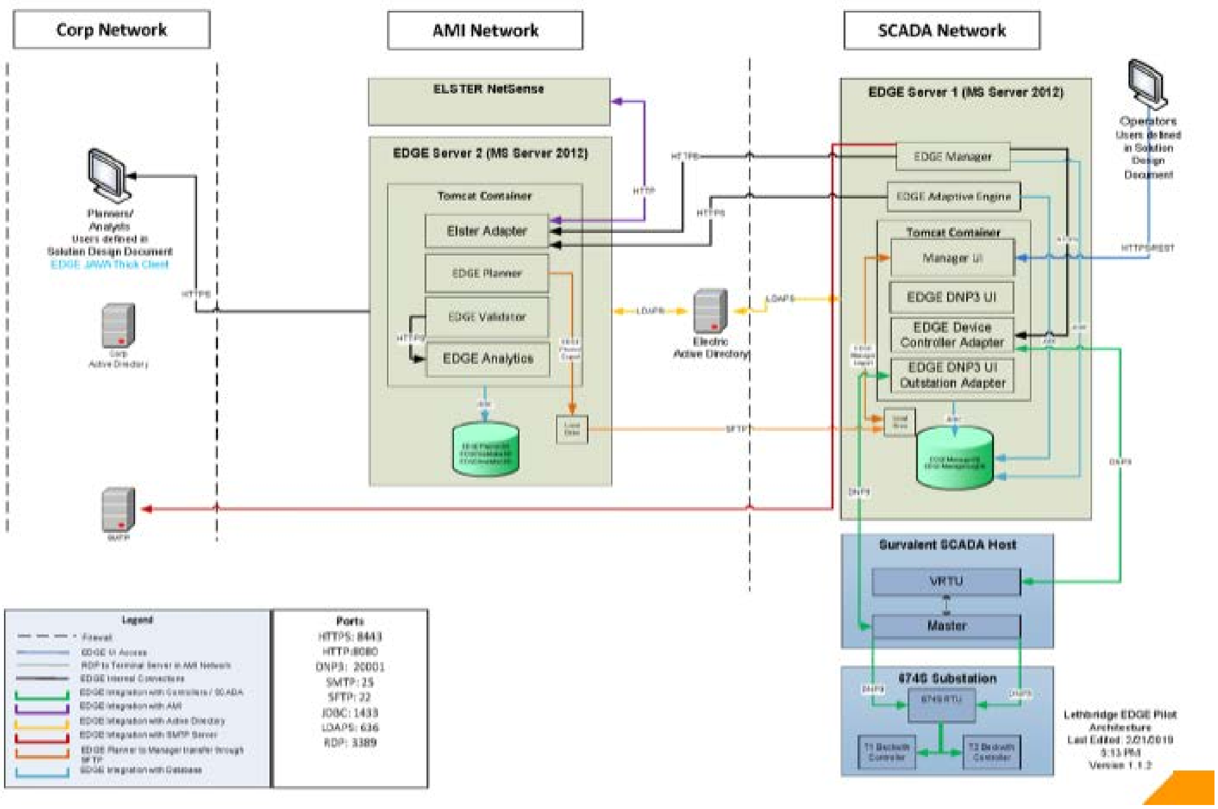


Figure 11– IT Architecture to support deployment of DVI EDGE within LEU systems

No controls are issued to field devices during monitor mode. At this point in time, technicians are simply testing that the right control outputs are being created by the system without actually invoking them on the LEU OLTCs.

The CVR system was allowed to run in monitor mode for one month to ensure system stability.

DVI EDGE Go-Live Mode

DVI returned to LEU on the week of March 12, 2018 for Workshop 2 and to move the EDGE CVR system from monitor to “go-live” mode. By Friday, March 16, 2018 the system was turned on and the first control signals were enabled between the EDGE CVR system and the LEU OLTCs at 674S Bowron substation.

Due to technical issues with the AMI system and how it was delivering information to the EDGE CVR system, it was decided to go back to monitor mode until those issues were resolved. During the week of April 2, 2016 the AMI issues were resolved with a patch provided from the

AMI vendor and the EDGE CVR system was enabled on a continuous basis starting on April 9, 2018. The system has been running continuously since that point in time.

DVI EDGE Continuous Operation

The only exception to continuous operation of the EDGE CVR system occurred when the physical power system required a change in the configuration of connected load due to network switching. The complexity and resources required to alter the node hierarchy information to effectively associate the customer meter information to the supply major power transformer was considered significant enough that the EDGE CVR system was disabled anytime the network configuration was anticipated to be altered for less than one month. This network switching type of event occurred only four times during the pilot in order to facilitate customer load after faults had occurred on the power system. After repairs were completed the power system was returned to normal configuration and EDGE CVR system was re-enabled.

The EDGE CVR system has run continuously since April 9, 2018 creating the control outputs to LEU transformers without any issues. LEU staff has completed analysis of customer voltage data using the EDGE CVR analytic tool, EDGE Planner.

The EDGE Planner can be used to identify distribution network voltage issues. LEU has made minor changes to a distribution network transformer's tap setting to solve a low voltage issue detected by EDGE Planner analysis. This correction of a "voltage outlier" allows LEU to continue lowering the distribution voltage in the area and seek further grid optimization opportunities through the analysis software.

In addition, EDGE Planner studies found a primary feeder line configuration where with a simple reconfiguration of the primary feeder network by simple switching activity could be optimized in order to provide further voltage reduction and energy savings to connected customers.

Weekly Meetings and Support from DVI

Weekly meetings were held between DVI and LEU technical staff to review operational logs and learn the functions of the EDGE Planner throughout the pilot program. This type of engagement is standard for DVI to ensure that customers are supported in the running of the DVI EDGE CVR system products in an attempt to maximize energy, economic, and environmental efficiencies.

Operational Results

CVR Factor Methodology and Calculations

The main objectives of the EDGE CVR pilot was to determine the technical, economic, and environmental benefits that can be associated with the operation of CVR in the LEU system. Additionally, LEU wanted to ensure that the EDGE CVR system did not produce any material issues in the provision of customer service to connected loads.

In order to quantify the above benefits the CVR factor had to be determined. CVR factor is by definition the change in energy that is required by distribution system loads when the voltage is changed to that connected load. The CVR_{factor} will vary based upon the physics of the connected load and therefore in a location, such as LEU, will change seasonally as connected load varies from heating in winter verses air conditioning in summer. At LEU the following CVR_{factor} calculations, in Table1, were completed during the pilot (see appendix X for presentation on CVR factor background and appendix Y for detailed reports):

Table 1: CVR_{factor} for LEU

Season	**OLTC T1 CVR_{factor}**	**OLTC T2 CVR_{factor}**
Winter	0.90	0.90
Summer	0.90	0.83

As highlighted in Figure 7 above, the OLTC T1 and OLTC T2 are the two On Line Tap Changers (OLTCs) that are controlled by the EDGE CVR system.

The CVR_{factor} results are considered “strong” by DVI who has observed and tracked factors through their work across North America. Although the range of factors that have been calculated range from 0.2 to 2.0, a CVR of 0.8 to 0.9 is considered top quartile performance when attempting to create energy and GHG efficiency reductions.

CVR Benefits

With the CVR_{factor} results available, it is possible to statistically calculate MW demand and MWh consumption reductions, or increases, achieved as a result of actively running CVR technology compared to operating the distribution system using traditional voltage regulation schemes. If the CVR technology is able to incrementally reduce the operating voltage of the distribution system while maintaining endpoint user voltage within the CSA band then there will be reductions in MW demand and MWh consumption of the connected load. This is what occurred during the pilot of the EDGE CVR system at LEU. The reduction of demand and consumption within LEU's system created by the efficiency gains of running the EDGE CVR system resulted in the following technical, economic, and environmental outcomes:

Table 2 – Pilot Results Summary for operations between April 1, 2018 – January 31, 2019

Pilot Reporting Goal	**Description**	**Results**
Technical	Average Voltage Reduction Total Energy Savings	1.14 % 554 MWh
Economic	Energy Savings to customers at 6.8 cents / kWh	$37,687
Environmental	Green House Gas Reduction	380 tonnesCO_2e

Lessons Learned and Outcomes of Results

Chasing Voltage Issues (Outliers)

LEU has not observed any controls coming from the EDGE CVR system that would result in concerns as to how the OLTC is being operated. The number of operations of the OLTC has been stable when comparing pre and post EDGE CVR system implementation records.

Only two events related to customer feedback have been recorded to date during operations in CVR mode. A low voltage concern was communicated from a large institutional customer during the operation of the EDGE CVR system the week of April 9, 2018. This was the result of the LEU AMI system not knowing voltages within the institution because the institution is metered at the primary entrance to the facility. As a primary metered customer, the secondary voltages downstream within the facility are not known to the AMI system. Therefore, the EDGE CVR system could not “adapt” to the condition. To resolve this issue the low set point for the EDGE CVR system was adjusted upward for the LEU transformer supplying the load to prevent the situation from reoccurring. A second feedback from the institution was received on September 27, 2018 regarding a low voltage condition concern. Although the voltage being applied to the primary service was well within the CSA band LEU simply raised the low voltage set point on the EDGE CVR system to eliminate the issue. Raising the low voltage set point reduces the ability of the EDGE CVR system to create efficiency savings for all customers and LEU is working with the institution to better understand the issues and look for solutions. LEU has also requested DVI to ensure that the voltage of the institution’s primary service entrance is always part of the set point calculations for system voltage to alleviate future concerns.

It is worth noting that no other customer connected to the EDGE CVR system registered any concerns with LEU during the pilot period.

Advantages to LEU as a result of deploying the EDGE CVR system that not anticipated were the inception of the pilot included the following:

- Expediting work on GIS data “clean up” to establish proper connectivity model to enable CVR. This work is required for other “smart grid” initiatives including the Outage Management System functionality now deployed by LEU;
- Using EDGE Planner study functionality has provided LEU Distribution Engineering group visibility of voltage performance on the connected load through analytical tools.

The analysis performed through EDGE Planner has allowed for correction of voltage outlier locations through transformer tap modification / correction, modifying operational topology of the network by strategic switching, and identifying areas with overall lower voltages during peaking conditions which will be considered for capital upgrading priority in future years;

- Learning opportunities were provided to LEU data systems staff to integrate the activities of the GIS, SCADA, AMI, and now CVR data base systems on both operational and corporate networks in a secure and efficient manner;

- Leveraging the combined expertise of DVI and LEU assisted in the deployment of CVR and better prepared LEU for upcoming work in the "smart grid" space; and

- Many dedicated hours were put into this pilot by the staff of LEU and DVI with positive outcomes for both entities and this created a positive outcome for all participants within the Alberta Smart Grid Consortium.

The key lesson learned during implementation of the EDGE CVR system is that it takes a dedicated team of data technicians to design, install, and provide trouble shooting during the early stages of the project. Significant time was spent researching complex topics as to how the AMI / SCADA / and EDGE softwares and databases interact.

The ongoing support from DVI provided through the workshops and now via weekly project meetings is essential to reach solutions on the integration issues that have been resolved and create the energy and environmental efficiencies being sought by the pilot.

Project Benefits and Impacts

GHG Emission Reductions

With the CVR factor measured and reported for LEU it is now possible to validate the energy and GHG emission reduction estimates made in the pilot project proposal. The level of voltage reduction during the trial did not achieve the 2% to 4% range of efficiency gains because of the operational philosophy that LEU placed on the trial. A conservative approach to voltage reduction on the distribution system was taken to insure LEU could monitor system and customer response closely. With the conservative approach energy savings were in the 1% range but LEU is confident that it can achieve savings in the 2% to 4% range as voltage is decreased into the lower half of the CSA band.

The original estimate for GHG benefits provided in the pilot proposal were estimated using the grid displacement factor of 0.64 tCO_2e/MWh that is published in the "Carbon Offset Emission Factor Handbook" Version 1.0 March 2015.

Actual Bowron 674S MWh consumption from October 1, 2016 to September 30 2017 is:

115 000 MWh

Electrical consumption is typically reduced between 2-4% with the use of CVR over the year. Therefore, anticipated MWh reduction will be:

2% Reduction = 2300 MWh to 4% Reduction = 4600 MWh

Therefore, the GHG reductions anticipated for Bowron 674S consumption over a one year period assuming no load growth on the substation would be between:

2300 MWh x 0.64 t/MWh = 1472 tCO_2e

And

4600 MWh x 0.64 t/MWh = 2944 tCO_2e

The above calculations are summarized in the Table 3 below. In addition, if the above calculations are extrapolated to include all LEU distribution system load, i.e. a full deployment to all 40 000 LEU customers and broadened to a 50% Alberta deployment on all distributed-connected loads, the corresponding GHG emission reduction are shown in the Table 3 below.

Table 3: Energy and GHG emission reductions for LEU pilot, LEU full deployment and broad Alberta deployment

CVR Deployment Level	Total Annual Load (MWh)	2% MWh Reduction (MWh)	GHG Reduction (tCO_2e)	4% MWh Reduction (MWh)	GHG Reduction (tCO_2e)
LEU – Bowron only	115,000	2,300	1,472	4,600	2,944
LEU – Complete Distribution System	841,000	16,821	10,765	33,642	21,531
50% Deployment on Distributed-Connected Load	9,167,000	183,340	117,338	366,680	234,675

Technical Objectives

Within the pilot project, we also had key performance metrics that we were looking to achieve, these were:

- CVR technology reduces electricity consumption by 2-4%;
  - The pilot project results were able to demonstrate a reduction by 1%. LEU operated the EDGE CVR system with a conservative approach in order to ensure that the EDGE CVR system could safely lower the operating voltage of the distribution system without impacting customers. During the EDGE CVR operations, voltage was reduced by, on average, 1.14%. During the high / low study that was used to gather the data to calculate the CVR factor, LEU had the distribution system "low" voltage set at 2% below long term traditional values. There were no customer concerns raised during the time when the system was set 2% lower than normal. Therefore, LEU expects that achieving a minimum of 2% savings is possible going forward.
- CVR technology causes minimal to no customer service inquiries
  - During the pilot project two customer concerns were received by LEU from a large connected institution. The concerns of low voltage were resolved in a timely fashion with the customer. It should be noted that no other concerns were brought forward by any other residential or commercial customers during the trial.

- CVR technology provides stable and predictable control of distribution system voltage
    - The pilot project demonstrated that the EDGE CVR system provided stable and predictable control to the OLTCs which provide delivery of power to the distribution system.
- CVR output reporting provides LEU operational and design staff with meaningful results that drive decision making related to where capital upgrading should be prioritized to resolve customer voltage issues.
    - The pilot project demonstrated that engineering design staff could use the EDGE CVR analysis tool, EDGE Planner, to perform analytical reviews of the voltages provided to all connected customers. The analysis allowed LEU to make corrections to distribution transformer taps, alter primary feeder line topology to improve the voltage profile of the line, and view customer voltages during peak loading conditions which can now be used to set priorities on capital renewal of ageing infrastructure areas.

Next Steps

During the pilot project, LEU applied for and received approval from NRCan through the Smart Grid Deployment Call for Proposals for funding to assist with deployment of CVR functionality over the complete LEU distribution system. Full deployment would equate to increasing the number of customer loads being serviced by DVI's EDGE CVR system from 10 000 to 40 000. The full deployment will also test the EDGE CVR system to a much greater range of customers including industrial, institutional, commercial, and residential entities as the pilot project focused mainly on residential customers. The Department of Electrical and Computer Engineering at the University of Alberta has expressed interest in collaborating on the full deployment in order to research the impact of deploying the EDGE CVR system on industrial loads. In addition, the University of Alberta would provide an independent validation of the CVR factors calculated using the DVI EDGE Validator software module to ensure the expected environmental and economic benefits can be achieved.

Before LEU can commit to a full deployment, there are two key initiatives that LEU and DVI need to demonstrate, which include:

- Ensuring that primary metered customer service entrance voltages can be permanently considered in the calculation of CVR set points. This will make certain that primary metered customer service entrance voltages are functional for the facility;

- Successfully upgrading to the DVI EDGE CVR version 1.7 with "auto-reconfigure" function proven. This will ensure that the EDGE CVR system can be re-established efficiently after switching of the power system has been performed. The pilot was performed using the EDGE CVR version 1.6.3 which did not include "auto-reconfigure" functionality. This led to the CVR function being turned off while the distribution system was not in its standard configuration due to the effort required to load a new node configuration hierarchy file into the EDGE CVR system.

Project Communications and Media

A press conference announcing the project was held in Lethbridge on Friday, May 4, 2018 to introduce the work being done in the pilot to the public. The media event agenda is included in Appendix Z. The press conference was organized by the City of Lethbridge with assistance and support from Alberta Innovates and technical assistance from DVI. Presentations to the media were provided by:

- Stewart Purkis – LEU
- Maureen Kolla – Alberta Innovates
- Mayor Chris Spearman – City of Lethbridge
- The Honourable Shannon Phillips - Minister of Environment & Parks, Minister Responsible for the Climate Change Office, and MLA for Lethbridge-West

Monthly project update meetings for the Alberta Smart Grid Consortium were organized and led by the LEU project manager. These update meetings allowed consortium members to keep up to date on the findings and operations of the pilot and identify tests and learnings that would be valuable for their operating scenarios.

On February 26, 2019, LEU hosted all members of the Alberta Smart Grid Consortium at LEU's Operations Center. The goal of the meeting was to insure that the findings of the pilot project were clearly presented to the group and establish contacts between consortium members for further follow up on this pilot and other collaborations now going on amongst the group.

Conclusions

1. The goal of demonstrating that the DVI EDGE CVR system could leverage AMI data into distribution system optimization was proven through the pilot. Energy efficiencies and associated GHG emission reductions were demonstrated. No significant concerns were raised by customers and a new level of knowledge that LEU is delivering approved CSA band voltages under all operating conditions was realized.
2. While running DVI EDGE CVR between April 9, 2018 and January 30, 2019, LEU reduced energy customer consumption on the distribution network by 554 MWh, resulting in $37,687 in energy savings to the customers and reducing GHG production by 380 tonnes CO_2e
3. Additional qualitative results were also achieved that include:
    a. The work done by LEU staff to install and operate the DVI EDGE CVR system allowed for expediting the deployment and enhancement of other LEU “smart grid” initiatives including work in outage management systems and engineering analytics systems;
    b. Optimizing LEU’s current infrastructure within the distribution system to create greater opportunities for energy savings;
    c. Analytical tools associated with EDGE Planner allow engineering staff to review distribution system performance during peak loading conditions to identify priorities for future infrastructure capital upgrading;
    d. Data management and optimization training for LEU staff;
    e. Knowledge dissemination to Alberta Smart Grid Consortium members; and,
    f. Building collaboration relationships with Alberta Smart Grid Consortium members.
4. The key DVI EDGE CVR system integration and deployment learnings are:
    a. Expect and manage data inconsistences within existing Electric Distribution data systems including GIS, AMI, and SCADA;
    b. The need to be open to changing the Operating philosophy;
    c. The opportunity to incorporate other smart grid initiatives during the pilot project; and,
    d. Resource requirements to implement smart grid technology.
5. The key operational learnings and opportunities for enhancements to the EDGE CVR system are:

a. LEU must work with DVI and large primary metered customers to insure voltages on the customer’s site, which are not monitored by the AMI system, are within the approved CSA band.
b. When the physical distribution system configuration is changed due to operational requirements the connectivity of customer meter points to their supply OLTC changes. LEU requires an efficient method to “re-configure” the EDGE CVR system to reflect the changes in the physical distribution system to insure that CVR functionality is maximized.

BYLAW 6144

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A BYLAW OF THE CITY OF LETHBRIDGE TO ESTABLISH THE CITY OF LETHBRIDGE ELECTRIC DISTRIBUTION TARIFF

****

WHEREAS the City of Lethbridge owns and operates a Municipal Electric Distribution Utility;

AND WHEREAS the City of Lethbridge Municipal Electric Distribution Utility has been designated as a Wire Service Provider pursuant to the ELECTRIC UTLITY ACT, S.A. 2003;

AND WHEREAS it is necessary to provide for the establishment of and the collection of fees for the provision of access to the City of Lethbridge distribution system and provincial electric transmission grid;

NOW THEREFORE, THE COUNCIL OF THE CITY OF LETHBRIDGE, DULY ASSEMBLED, HEREBY ENACTS AS FOLLOWS:

1. Bylaw 6144, the City of Lethbridge Electric Distribution Tariff Bylaw is hereby established.

2. The 2019 Electric Distribution Rates are set forth in following Rate Schedules:

   Rate Code 991 Standard Single Phase Distribution
   Rate Code 992 Medium Single Phase Distribution
   Rate Code 994 General Three Phase Distribution
   Rate Code 995 Medium Three Phase Distribution
   Rate Code 996 Large Three Phase Distribution
   Rate Code 997 Primary Distribution
   Rate Code 998 Public Lighting Distribution
   Rate Code 999 Unmetered Distribution

3. There is hereby established a City of Lethbridge Local Access Fee – Rider “A” attached hereto as Schedule “A”.

4. There is hereby established a Balancing Pool Consumer Allocation – Rider “B” attached hereto as Schedule “B”.

5. There is hereby established an AESO Rate DTS – Rider “C” attached hereto as Schedule “C”.

6. The Terms and Conditions are set forth in the following Terms and Conditions of Electric Service attached hereto.

7. Bylaw 6091 and amendments thereto is hereby repealed.

8. This Bylaw shall take effect on the 1st day of January, 2019

READ A FIRST TIME this ________ day of ______________________, A.D. 2018

_________________________________ _____________________________
MAYOR CITY CLERK

READ A SECOND TIME this ________ day of ___________________, A.D. 2018

_________________________________ _____________________________
MAYOR CITY CLERK

READ A THIRD TIME this ________ day of _____________________, A.D. 2018

_________________________________ _____________________________
MAYOR CITY CLERK

City of Lethbridge
ELECTRIC UTLITY

Electric Distribution Tariff
Rate Schedule

City of Lethbridge
Bylaw 6144

Effective:
January 1, 2019

City of Lethbridge
Infrastructure Services
Electric Utility

Document

Copies of this document available at:
City of Lethbridge City Hall
Electric Design and Administration
290 – 7th Street, North
Lethbridge, Alberta T1H 6K2

Electronic version (pdf) of this document available at:
http://www.lethbridge.ca/bylaws

Other related documents:
Technical Terms and Conditions for Distribution Wire Access (2014)
Guideline for Power Quality (2013)
Distribution Tariff Fee Schedule (2017)
City of Lethbridge Code of Conduct Compliance Plan (2016)
Electric Distribution Capital Investment Policy (2017)

Contact Information:
Office: 290 – 7th Street, North Lethbridge, Alberta T1H 6K2
Office Hours: Monday to Friday, 8:00 a.m. - 4:30 p.m.
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Document Author:
City of Lethbridge Electric Utility
Regulatory & Rates
Infrastructure Services
City of Lethbridge

Contents

Electric Distribution Rates

Electric Distribution Tariff

The current Electric Distribution Tariff includes approved Electric Distribution Rates and Terms and Conditions of Electric Service.

Electric Distribution Rates

Current Electric Distribution Rates include approved Distribution Access Rates and Transmission Access Rates herein for the current Effective Rate Period.

Effective Rate Period

Current Electric Distribution Rates (Transmission and Distribution components) take effect January 1, 2019 (midnight December 31, 2018) and remain in effect until replaced by a new or amended rate approved by the City Council of the City of Lethbridge.

Effective January 1, 2010 the MCAF no longer applied to Rider B.

The application of Rider C took effect January 1, 2010.

Rate Application Authority

The City of Lethbridge undertakes to apply Electric Distribution Rates as per Section 102 of Electric Utility Act of the Province of Alberta and Electric Utility Act Distribution Tariff Regulation 162/2003.

Rate Approval Authority

The City of Lethbridge Electric Utility undertakes to apply current Electric Distribution Rates under the authority of City of Lethbridge Bylaw 5613.

Terms and Conditions

Electric Distribution customers are subject to Terms and Conditions of Electric Service and all published related documents.

Price Adjustments and Riders

Electric Distribution Tariff price adjustments and riders noted herein are provided for information and are not intended to be part of the City of Lethbridge Electric Distribution Tariff. Adjustments and Riders retain specific approvals, effective periods and terms and conditions.

City of Lethbridge Local Access Fee

The City of Lethbridge Local Access Fee (LAF) is a surcharge applied by the City of Lethbridge applicable to all service provided under the Electric Distribution Tariff.

The Current LAF is contained under Schedule A.

Definitions

Billing Period	The period of time for which distribution rate calculations apply.
Contract Demand	The agreed contract minimum and maximum service load available as determined under a *Distribution Service Agreement* between the customer and the City of Lethbridge Electric Utility.
Contract Maximum	Means the maximum kVA established under a *Distribution Service Agreement* a customer agrees to demand and the City of Lethbridge Electric Utility will provide.
Contract Minimum	Means the minimum kVA established under a *Distribution Service Agreement* for which a customer is charged.
Contract Ratchet	Means the maximum recorded kVA greater than Contract Maximum over the past 12 months.
Cumulative Meter	A metering device that measure system usage by continuously adding current use to prior use. Current consumption is determined as the difference between a current reading and a prior reading.
Customer	Means the recipient of electric distribution services.
Customer of Record:	Means the party responsible for the payment of services**.**
Demand	Means the service load or rate at which electric energy is delivered/taken at a given point in time measured in kVA or MVA.
Demand Meter	Means the metering device used to determine Demand.
Distribution Access	Means access to the City of Lethbridge Electric Distribution System.
Distribution Service Agreement	Means an agreement between the City of Lethbridge Electric Utility and a distribution service connection customer.
Electric Service Area	The area determined under the *Hydro and Electric Energy Act* in which the City of Lethbridge as owner of an electric distribution system may distribute electricity.
Interval Meter	Means a meter that measures, at intervals of 60 minutes or less, the amount of electricity consumed, and satisfies the standards for revenue collection under the *Electricity and Gas Inspection Act* (Canada) and the *Weights and Measures Act* (Canada).
kVA	Means Kilovolt ampere and is the unit of measure used for Demand, Contract Maximum, Contract Minimum and Contract Ratchet.
kWh	Means Kilowatt-hour (one kilowatt of power supplied/taken for one hour) and is the unit of measure used for System Usage.
Load Profile	Means the measured or determined System Usage throughout a period of time.

MVA	Means 1,000 kVA
Off-Peak	Means System Usage other than On-Peak system usage.
On-Peak	Means System Usage between the 07:00 hours and 23:00 hours, Monday through Saturday excluding: all Sundays, New Year's Day, Good Friday and Christmas Day.
Primary Voltage	Means a Service Connection at the City of Lethbridge distribution system high voltage level.
Ratchet	Means the highest demand in the last 12 months
Regulated Rate Option	Means the Tariff an owner of an electric distribution system must prepare for the purpose of recovering prudent costs for providing electric energy services to eligible customers that are not enrolled with a retailer.
Secondary Voltage	Means the output of a load-supply City of Lethbridge Electric Distribution Transformer.
Service and Facility	Means ongoing services, plant, works, equipment necessary to provide electric distribution and transmission access.
Service Connection	Means the point of connection to the City of Lethbridge Electric Distribution System.
Single-Phase Connection	Means a 3-wire connection point.
System Usage	Means the use of the City of Lethbridge Electric Distribution System and Alberta Interconnected Electric System measured in kWhs.
Totalized	Refers to the combining of 2 or more services at one site for billing purposes.
Three-Phase Connection	Means a 4-wire connection point.
Transmission Access	Means access to the Alberta Interconnected Electric System.
Unmetered	Means a Service Connection without a City of Lethbridge Electric Utility provided metering device.

2019 Electric Distribution Rates

Rate Code	Distribution Rate Description
991	**Standard Single Phase Distribution Rate** – for single phase service metered through a single cumulative or demand meter. ▪ Demand less than 12 kVA
992	**Medium Single Phase Distribution Rate** – for single phase service metered through a demand meter. • Demand of 12 kVA or greater
994	**General Three-Phase Distribution Rate** – for three phase service metered through a single demand meter. ▪ Demand less than 150 kVA
995	**Medium Three-Phase Distribution Rate** – for service through a three-phase connection at secondary voltage metered through a single demand meter. ▪ Demand of 150 kVA or greater and less than 300 kVA
996	**Large Three-Phase Distribution Rate** – for service through a three-phase connection at secondary voltage metered through a single interval meter. ▪ Demand of 300 kVA or greater
997	**Primary Distribution Rate** – for service through a three-phase connection at primary voltage metered to customer transformation through a single interval meter. ▪ Demand of less than15 MVA
998	**Public Lighting Distribution Rate** – for unmetered municipally owned and provincial owned public lighting systems and individual customer subscribed unmetered security lighting. .
999	**Unmetered Distribution Rate** – for unmetered service connections with small, consistent and predictable system usage.

Rate Code 991: Standard Single Phase Distribution

Service

Single phase service connected within the City of Lethbridge electric service area
Metered through a single cumulative or demand meter
For monthly demand less than 12 kVA

Transmission Access Rate

a) System Usage Charge	0.0245	$ per kWh
b) Service and Facilities Charge	0.2537	$ per day

Distribution Access Rate

a) System Usage Charge	0.0194	$ per kWh
b) Service and Facilities Charge	0.8699	$ per day

- The minimum daily charge is the daily combined distribution and transmission service and facilities charge
- The billing period is monthly
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by City Council may be applied to this rate.

Rate Code 992: Medium Single Phase Distribution

Service

Single phase service connected within the City of Lethbridge electric service area
Metered through a demand meter
System demand of 12 kVA or greater

Transmission Access Rate

a) System Usage Charge	0.0140	$ per kWh
b) Service and Facilities Charge	0.0000	$ per day
c) Demand Charge	0.0922	$ per kVA per day

Distribution Access Rate

a) System Usage Charge	0.0012	$ per kWh
b) Service and Facilities Charge	0.5050	$ per day
c) Demand Charge	0.0879	$ per kVA per day

- The minimum daily charge is the daily combined distribution and transmission demand charge plus the daily Service and Facilities Charge.
- The billing period is monthly
- Demand charge based on the greater of “metered” or “ratchet” demand.
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by city Council may be applied to this rate.

Rate Code 994: General Three-Phase Distribution

Service

Three phase service connected within the City of Lethbridge electric service area
Metered through a single demand meter
System demand less than 150 kVA

Transmission Access Rate

a) System Usage Charge	0.0140	$ per kWh
b) Service and Facilities Charge	0.0000	$ per day
c) Demand Charge	0.1536	$ per kVA per day

Distribution Access Rate

a) System Usage Charge	0.0009	$ per kWh
b) Service and Facilities Charge	0.4040	$ per day
c) Demand Charge	0.1286	$ per kVA per day

- The minimum daily charge is the daily combined distribution and transmission demand charge plus the daily Service and Facilities Charge.
- The billing period is monthly
- Demand charge based on the greater of "metered" or "ratchet" demand
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by city Council may be applied to this rate.

Rate Code 995: Medium Three-Phase Distribution

Service

Service connected within the City of Lethbridge electric service area
Serviced through a three-phase connection at secondary voltage
Metered through a single demand meter
System demand of 150 kVA or greater and less than 300 kVA

Transmission Access Rate

a) System Usage Charge	0.0128	$ per kWh
b) Service and Facilities Charge	0.0000	$ per day
c) Demand Charge	0.2080	$ per kVA per day

Distribution Access Rate

a) System Usage Charge	0.0010	$ per kWh
b) Service and Facilities Charge	0.3990	$ per day
c) Demand Charge	0.2020	$ per kVA per day

- The minimum daily charge is the daily combined distribution and transmission demand charge plus the daily Service and Facilities Charge.
- Demand charge based on the greater of "metered" or "ratchet" demand
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by city Council may be applied to this rate.

Rate Code 996: Large Three-Phase Distribution

Service

Service connected within the City of Lethbridge electric service area
Serviced through a three-phase connection at secondary voltage
Metered through a single interval meter
System demand of 300 kVA or greater

Transmission Access Rate

a) On-Peak System Usage Charge	0.0158	$ per kWh
b) Off-Peak System usage Charge	0.0131	$ per kWh
b) Service and Facilities Charge	0.0000	$ per day
c) Demand Charge	0.1704	$ per kVA per day

Distribution Access Rate

a) System Usage Charge	0.0012	$ per kWh
b) Service and Facilities Charge	14.3871	$ per day
c) Demand Charge	0.1920	$ per kVA per day

- The minimum daily charge is the daily combined distribution and transmission demand charge plus the daily Service and Facilities Charge.
- The billing period is monthly
- Demand charge based on the greater of "metered", or "ratchet" demand:
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- On Peak System Usage Charge based on usage between the 07:00 and 23:00 hours, Monday through Saturday excluding all Sundays, New Year's Day, Good Friday and Christmas Day
- Additional riders approved by city Council may be applied to this rate.

Rate Code 997: Primary Distribution

Service

Service connected within the City of Lethbridge electric service area

Serviced through a three-phase connection at primary voltage to customer transformation

Metered through a single interval meter
System demand of less than 15 MVA

Transmission Access Rate

a) On-Peak System Usage Charge	0.0161	$ per kWh
b) Off-Peak System usage Charge	0.0132	$ per kWh
b) Service and Facilities Charge	0.0000	$ per day
c) Demand Charge	0.1819	$ per kVA per day

Distribution Access Rate

a) System Usage Charge	0.0011	$ per kWh
b) Service and Facilities Charge	12.6961	$ per day
c) Demand Charge	0.0880	$ per kVA per day

Transmission Access Rate

- The minimum daily charge is the daily combined distribution and transmission demand charge plus the daily Service and Facilities Charge.
- The billing period is monthly
- Demand charge based on the greater of "metered", or "ratchet" demand:
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- On Peak System Usage Charge based on usage between the 07:00 and 23:00 hours, Monday through Saturday excluding all Sundays, New Year's Day, Good Friday and Christmas Day
- Additional riders approved by city Council may be applied to this rate.

Rate Code 998: Public Lighting Distribution

Service

Service connected within the City of Lethbridge electric service area

For unmetered public lighting systems

Public lighting system includes all municipally managed lighting distribution services and all provincially managed lighting distribution services

Public lighting includes all customer subscribed security lighting (dusk to dawn) provided directly by the City of Lethbridge

Transmission Access Rate		
a) System Usage Charge	0.0497	$ per kWh
Distribution Access Rate		
a) System Usage Charge	0.2862	$ per kWh
Minimum Billing Charge	1.00	$ per day

- The minimum daily charge is the minimum billing charge or the Distribution Access Rate plus the Transmission Access Rate whichever is greater.
- The billing period is monthly
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by City Council may be applied to this rate
- Billing period system usage is based on the sum of the estimated energy load profile for all serviced lighting under this rate as determined by the City of Lethbridge Electric Utility
- Public lighting includes street, roadway, highway, park, walkway, unmetered traffic sign lighting and customer subscribed security lighting

Rate Code 999: Unmetered Distribution

Service

Service connected within the City of Lethbridge electric service area

For unmetered connections with small, consistent and predictable system usage as determined by Lethbridge Electric Utility

Transmission Access Rate		
a) System Usage Charge	0.0421	$ per kWh
Distribution Access Rate		
a) System Usage Charge	0.2046	$ per kWh
Minimum Billing Charge	1.00	$ per day

- The minimum daily charge is the minimum billing charge
- The billing period is monthly
- The City of Lethbridge Terms and Conditions of Electric Service apply to this rate
- The City of Lethbridge *Rider A* Local Access Fee (LAF) is applied to total charges under this rate
- Additional riders approved by city Council may be applied to this rate.
- Billing period system usage is based on the estimated system usage load profile for each service site as determined by the City of Lethbridge Electric Utility

ARTICLE 8 - METER DATA MANAGEMENT

8.1 Responsibilities

- The MDM is the entity responsible to provide “settlement quality” data to stakeholders as outlined in the SSC.
- The MDM shall be the sole source to manage consumption and interval data for interval and cumulative meters, collecting meter data, validating and estimating interval and cumulative mater data, storing historical data, and reporting data to the LSA and Retailers. The MDM shall ensure the interval and cumulative historical meter data is available to an authorized party at a cost outlined in the Fee Schedule.
- Any metering data requests including special reports, graphs, and analysis shall be charged as outlined in the Fee Schedule.
- LEU will be the sole source of revenue metering information for all market participants in the LEU service area.
- LEU validation editing and estimation standards will be reviewed and modified form time to time as appropriate.
- LEU will read all meters in its service territory in accordance with the Meter Reading Schedule. Retailers are responsible for acquiring information about Meter Reading Schedules from LEU.
- Estimation algorithm information is available upon request to an end use Customer or a Person (Customer’s Agent or Retailer) who is authorized by the end user.
- An accurate record will be kept by LEU of meter readings that will be the basis for the Load Settlement for each metered site.

8.2 Meter Reading Concerns/Disputes

It is the Retailer’s responsibility to assist Customers who are concerned about their consumption levels and provide possible causes for their high consumption.

If a Retailer disputes a read for whatever reason, the Retailer may request an Off-Cycle Read.

LEU will read any meter provided by LEU at the request of the Retailer subject to the charges set out in the Fee Schedule. A request is considered to be completed when a reading is obtained, or when, 3 physical attempts or 2 physical attempts and 1 phone call, have been made.

In the event that the Off-Cycle Read shows that a prior recorded reading is incorrect, the costs of the Off-Cycle Read will be waived.

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Appendix X

CVR Factor Calculation: The EDGE Approach

Alberta Innovates Monthly Update

June 6, 2018

CVR Factor: What and Why?

CVR Factor

- Quantifies a particular load's response to voltage change
- Varies by customer load types, with regional trends
- North America estimated at 0.8 – 1.2
  - Inland Power and Light (Spokane) reported 0.93 in NEEA 1207
- Calculated by node, used to calculate energy savings

$$CVR_f = \frac{\%\Delta E}{\%\Delta V}$$

Pairing ON and OFF Hours

CVR OFF		CVR ON
Record 1		Record 2
TX #1	=	TX #1
Status	<>	Status
Temperature	+/- 1˚	Temperature
Avg. Temp Prior 6 hrs	+/- 1˚	Avg. Temp Prior 6 hrs
Avg. Temp Prior 72 hrs	+/- 1˚	Avg. Temp Prior 72 hrs
Humidity	+/- 1%	Humidity
Volts	Δ Volts	Volts
Hour Type (hourly index)	+/- 1%	Hour Type (hourly index)
kW load	Δ kW	kW load
Custom filter 1	+/- 1	Custom filter 1
Custom filter 2	+/- 1	Custom filter 2
Custom filter 3	+/- 1	Custom filter 3

Pairing parameters:

- ✓Weather
- ✓Hourly Index (non-weather factors)
- ✓3 Custom Filters

Hours similar on these factors will isolate the correlation between load and voltage.

CVR turned on and off to create data (Can be scheduled in EDGE Manager)

OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON

Calculations

CVR Factor

- Form ON/OFF pairs and calculate each CVR_f
- Calculate mean CVR_f for all pairs

$$CVR_f = \frac{\%\Delta E}{\%\Delta V}$$

Energy Savings

- Compare each ON hour's voltage to baseline voltage (OFF)
- Use mean CVR_f to calculate energy savings for each hour
- Sum energy savings for ON hours to get total savings

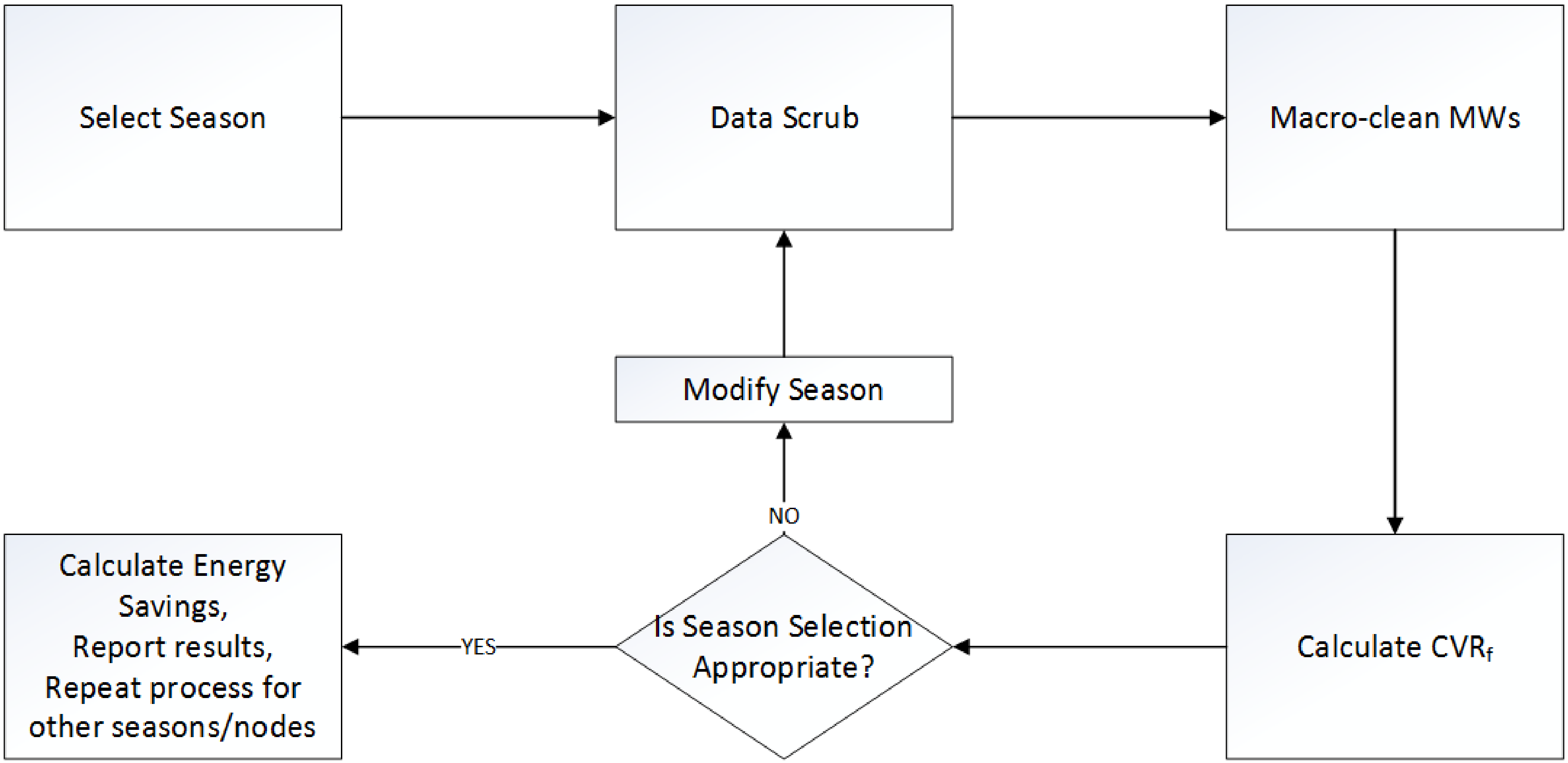
EDGE Validator

DVI’s proprietary implementations of the calculations of CVR factor and energy savings are covered by **US patents 9,563,218 B2** and **9,847,639 B2**.

Additional Considerations

- Normalize by customer count
- Exclude holidays (e.g. Alberta Family Day)
- Can account for load growth
  - Percent load growth
  - Similar transformer for comparison
- Select a homogeneous season
- Exclude switching or other load anomalies

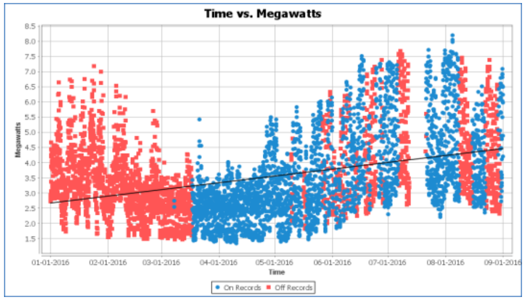
M&V Process Flow



Remove Anomalies

Post Nation

Louisiana flooding is the country's 'worst natural disaster' since Hurricane Sandy, Red Cross says



Note: dates are month-day-year; flooding outages lasted several days

Lethbridge Analysis

Bowron Substation

- Analysis still underway for winter CVR_f
- Need to incorporate U of L generation data
- LEU plans to conduct a high/low voltage study this summer
  - 7 weeks alternating high and low set points
  - July and August should form a consistent season
- DVI will calculate summer CVR_f from study

Appendix Y-1

High-Low Study Report

Prepared by DVI for Lethbridge

10 July 2018

Contents

Executive Summary

The measurement and verification (M&V) phase of the EDGE® pilot for Lethbridge uses EDGE Validator software to calculate the energy savings recorded over a period of time when EDGE Manager was operating CVR and/or DR on the pilot nodes. Typically, a few months of data are needed to obtain a statistically valid result. To shorten this time period, EDGE projects include a concentrated study period in which the voltage on a node is varied between a high and low voltage set point or bandcenter. The high-low study is performed prior to EDGE go-live, using fixed set points on LTCs and regulators.

The first value calculated is the average conservation voltage reduction factor (CVR factor or CVR_f), which is the percent change in energy for each percent change in voltage.

$$\mathrm{CVR_f} = \frac{\%\Delta \mathrm{E}}{\%\Delta \mathrm{V}}$$

The CVR factor is calculated through a pairing process that matches an hour from the low voltage periods to an hour from the high voltage periods. The change in energy and change in voltage are calculated for each pair to calculate the pair's CVR_f. The average CVR_f is taken as the resulting CVR_f for that node in that season.

The latest release of EDGE Validator did not find enough pairs to calculate a statistically acceptable CVR factor during the 6 weeks of the high-low study. Therefore, DVI used an enhanced regression-informed pairing process that is under consideration for inclusion in a future release of Validator. This new process improved the number of pairs and gave a statistically acceptable result for T2, but for T1 it did not find a valid CVR factor.

Once EDGE has been running CVR on the node for a few months, the CVR_f may be calculated again by comparing CVR On to CVR Off hours, rather than constant high and low voltage periods. CVR factors should be calculated separately for different seasons, because they depend on the type of loads connected to the circuit, and how sensitive those loads are to changes in voltage.

The CVR_f will be used to calculate energy savings for CVR On periods, using the reverse equation and the recorded voltage for each On hour (compared to the baseline voltage during the Off period).

$$\%\Delta \mathrm{E} = \mathrm{CVR_f} \times \%\Delta \mathrm{V}$$

Lethbridge provided data for the period of 9 January – 21 February for the 674S T1 and T2 nodes. The study was conducted during the winter season. Generation data from the University of Lethbridge was added to the substation load for T2 to calculate the total load on the two lines served by T2.

The data for T1 did not show a statistically significant relationship between voltage and load, so a result could only be obtained for T2. The calculated CVR factor is given in the table below.

Node	Season	# Pairs	CVR_f	σ	p-value	95% Confidence
674S T1	Winter	-	-	-	-	-
674S T2	Winter	120	0.92	0.85	0.0000	0.77 – 1.07

The calculated energy savings during the low periods is given in the next table; the CVR factor for T2 was used to calculate energy savings for both T1 and T2. This is an estimate of what savings may be available during EDGE operation during the winter season. In contrast to the fixed set points of the high-low study, EDGE will lower the voltage at much as possible based on feedback from AMI bellwether meters.

Node	Season	Dates	CVR_f	Voltage Reduction (%)	Energy Savings (%)	Energy Savings (MWh)
674S T1	winter	16 Jan – 21 Feb	0.92	1.54%	1.42%	76.03
674S T2	winter	16 Jan – 21 Feb	0.92	1.36%	1.25%	29.08

Data Collection

Lethbridge conducted the high-low study during the period of EDGE solution design and installation.

Parameter	Value	Notes
Existing settings:		
Existing Set Point	123.5	
Bandwidth	4	
SCADA Low Voltage Alarm	120?	Can change if needed to avoid setting off
SCADA High Voltage Alarm	125?	Can change if needed to avoid setting off
Line Drop Compensation	off	
Set points for study:		
Low Set Point	121.5	Tap would not raise until V < 119.5 V
High Set Point	124.5	Tap would not lower until V > 125.5 V
Bandwidth	6	accidentally set to 3 for one week (more tap changes)
SCADA Low Voltage Alarm	no change	Can change if needed
SCADA High Voltage Alarm	no change	Can change if needed
Line Drop Compensation	off	

The study was conducted over a period of 6 weeks.

Week Beginning	Voltage	Notes
January 9	high	
January 16	low	
January 24	high	
January 31	low	
February 7	high	

February 14	low	

Methodology

The information in the Methodology section and its subsections is confidential and is provided under non-disclosure agreement.

EDGE Validator's goal is to first determine the average CVR factor for a particular EDGE node for a particular season, and then use that to calculate the energy savings in that season. An EDGE node is a substation transformer (or set of parallel transformers) and all its downline facilities and meters, and a node's CVR factor is an attribute of the connected loads. Loads may be generally classified by their percentage of constant impedance (square dependence between voltage and load), constant current (linear dependence between voltage and load), and constant power (no dependence between voltage and load). Industry research[1] has studied the voltage dependence of individual appliances. Validator calculates the overall CVR factor for the node. This value will vary between nodes, so it's important to calculate it for at least the first few EDGE nodes to understand the range of how a utility's load responds to CVR.

Data Requirements

Validator uses 4 types of data for its analysis.

- Electrical observation data – *hourly substation-level power and voltage*
- Weather data – *hourly temperature, relative humidity, and user-selected variables for a weather station located near the node*
- CVR status data – *the CVR On/Off status, exported from EDGE Manager*
- Customer count data – *the number of customers on the node at different historical dates, used to normalize load per customer as a method of incorporating new customer growth*

Calculations

CVR Factor

EDGE Validator calculates CVR factor using a process that pairs hours from the CVR On period with hours from the CVR Off period. The pairing compares the change in a number of measurements found to be significant in their effect on loading:

- Temperature
- Average temperature over the past 6 hours
- Average temperature over the past 72 hours
- Relative humidity

[1] K. P. Schneider *et al.*, "Evaluation of Conservation Voltage Reduction (CVR) on a National Level," Pacific Northwest National Laboratory, Richland, WA, Rep. PNNL-19596, Jul. 2010.

- Hourly index – *a factor calculated by Validator that measures NON-weather-related loading characteristics for each hour of the week, e.g. load at 10 p.m. on Thursday tends to be higher than weather characteristics would predict*
- Megawatts – *used to exclude pairs with large changes in load due to factor other than CVR (such as switching); normalized by customer count*
- Voltage – *used to ensure a minimum change in voltage, to avoid dividing by near-zero in the* CVR_f *equation*

For all parameters except voltage, the difference between the On and Off hours must be *less than or equal to* the configured value in order for the hours to form a pair. For voltage, the difference must be *greater than or equal to* the configured value.

Validator compares every On hour with every Off hour, using the pairing parameters in the above list. All candidate pairs that fall within the parameter limits are given a pairing score, with smaller differences (more similar hours, e.g. smaller temperature difference) receiving a higher score. Validator then selects the pair with the highest score, adds that pair to its collection, and excludes all other candidate pairs that use the same On and Off hour as the selected pair. Then it proceeds to select the next highest score. In this way, Validator will generate as many pairs as possible such that:

- All pairs meet the specified pairing parameters.
- Each hour belongs to only one pair.
- The highest-scoring pairs are selected first.

Because Validator uses the highest score rather than a randomized pairing order, this method also ensures that the same pairing inputs will produce the same results every time the analysis is run.

Once Validator has a collection of valid pairs, it will calculate the CVR factor for each pair by dividing the percent change in energy by the percent change in voltage.

$$\mathrm{CVR_f} = \frac{\%\Delta \mathrm{E}}{\%\Delta \mathrm{V}}$$

At this point, outlier pairs are removed from the population, based on the specified Outlier parameter, which uses the median absolute deviation (MAD). From this final population, the mean CVR factor is calculated and displayed in the Validator user interface.

Accepting a Result

By convention in the statistics field, the minimum number of pairs required is 30, but in DVI's experience, the best results come with populations of nearly 100 pairs, or more. Having 100 pairs usually results in representation from all times of day. The standard deviation should not be much larger than the mean. The p-value is calculated to determine whether the difference in load between On and Off hours is significant; in this analysis the p-value was expected to be less than 0.05. If the p-value is out of bounds, the standard deviation is too large, or insufficient pairs were found, the analysis may be repeated with relaxed pairing parameters to generate more pairs and a more statistically sound result.

The final step is to view Validator's graphs of *CVR Factor vs. On Time* and *CVR Factor vs. Off Time*. The trendline should cover less than a 0.5 change in CVR_f during the analysis period. If the trend is larger, than the results are not consistent across the selected season, and the start and/or end dates should be adjusted. The *Megawatts vs. Time* and *Temperature vs. Time* graphs can aid in finding a consistent period to use as the season for analysis.

Using a Calibrating CVR Factor

The megawatt filter excludes pairs with a large difference in power (typically > 5% difference), but since the M&V process is *looking for* a difference in power (energy savings), it has an asymmetric effect. Therefore, a calibrating CVR factor is specified for the pairing process, which adjusts the megawatt filter to be symmetrical around the change in power expected from that calibrating CVR_f. The methodology used here is to begin with a calibrating CVR_f of zero and to set the megawatt filter very wide at 30% and the outlier filter to 5 MAD. This initial pairing is considered round 1. The resulting median CVR_f is then used as the calibrating CVR_f in round 2. In addition, the megawatt filter is tightened to 5% and the outlier filter is tightened to 2 MAD. The resulting mean CVR_f from round 2 is used as the result of the pairing process.

Adjusting the Pairing Parameters

Initially, the pairing parameters are set to a constraint of 1 for temperature and hourly index, 10% for relative humidity, and 2 volts for voltage. The calibrating CVR_f (round 1 / round 2) process is used to obtain a CVR_f. This result is checked for the number of pairs and the size of the standard deviation vs. the mean CVR_f. If there are at least 100 pairs and the standard deviation is no more than double the mean, then the result is accepted.

If the result is not accepted, the pairing constraints are relaxed, repeating the calibrating CVR_f process with the new parameters. First the temperature and hourly index filters are set to 2 and the relative humidity is set to 20%. If this new set of constraints doesn't result in an accepted answer, then the voltage is relaxed by reducing the minimum separation to 1 volt. Finally, if the result is still not accepted, the megawatt filter is relaxed to 10% during round 2 of the calibrating CVR_f process.

The table below shows the 4 sets of pairing constraints.

Set	ΔT (°F)	ΔT_6 (°F)	ΔT_{72} (°F)	ΔRH (%)	ΔV (V)	ΔHI (0-10 scale)	Calibrating CVR_f Process: Round 1 %MW / Outlier	Calibrating CVR_f Process: Round 2 %MW / Outlier
Set 1	1	1	1	10	2	1	30 / 5	5 / 2
Set 2	2	2	2	20	2	2	30 / 5	5 / 2
Set 3	2	2	2	20	1	2	30 / 5	5 / 2
Set 4	2	2	2	20	1	2	30 / 5	10 / 2

The CVR_f calculated in round 1 of each set is never accepted as an answer; it's used only to calculate the calibrating CVR_f for round 2 of each set. The result of round 2 may be accepted as the answer. For set 1, the result is accepted if there are at least 100 pairs and the standard deviation is no more than double the mean. If later sets of pairing parameters are needed, then the result from each set is compared to the result of the previous set. A flow chart is available documenting the precise comparisons for each set. The overall aim is to accept the answer with the greatest number of pairs and tightest standard deviation.

In order to find an acceptable answer, at least one result must include at least 75 pairs with a standard deviation no more than double the mean CVR_f. If no answer is accepted, DVI will collaborate with the utility to apply additional statistical techniques in search of a statistically acceptable answer for CVR_f.

Enhanced Validator Process with Regression

DVI has developed an enhanced Validator process (currently a mix of automated and manual steps) that applies stepwise linear regression to determine which input parameters are significant in predicting the resulting load (kilowatts per customer). The regression considers the input parameters from Validator 1.6.3 as well as derived parameters. Temperature is replaced by cooling degree hours and heating degree hours to create two linear relationships.[2] A stepwise linear regression selects only those parameters that are significant in predicting the resulting load. The end result of the regression is a set of significant parameters and their coefficients in the regression equation that predicts load.

The significant parameters or *predictors* are then used in a modified pairing process. The pairing constraints for weather and hourly index are derived from their coefficients in the regression model. The derivation uses the regression equation and varies each predictor independently, holding other predictors constant, to determine how much absolute change in that predictor causes a 5% change in load around its median. These constraints are recorded. The constraint for voltage is set to at least 1% separation. The modified pairing process uses these constraints along with a two-round process to determine the calibrating CVR_f, similar to the process used with Validator v1.6.3 as described above.

The result of round two includes a CVR_f, standard deviation, and number of pairs. The standard deviation is checked to ensure it is no more than double the CVR_f. For the number of pairs, the goal is to have just over 100 pairs.

If the number of pairs greatly exceeds 100, that means an answer is possible that gives fewer pairs at a lower error. In that case, the modified pairing process is run again using a lower error percentage of 2.5%. Round 1 and 2 are repeated to determine the calibrating CVR_f. The result of round 2 of this new set of pairing constraints is checked against the targets for standard deviation and number of pairs.

The error between predicted and observed load is varied in order to zero in on the minimum error possible with over 100 pairs, using a method analogous to Euler's method or Newton-Raphson, choosing the next error percentage using a step size half as large as the previous step, increasing the error percentage if there were under 100 pairs and decreasing it if there were over 100 pairs.

---

[2] During cooling season, load increases with *increasing* temperature, while during heating season, load increases with *decreasing* temperature. Cooling degree hours and heating degree hours are calculated as the difference between 65°F and temperature, and therefore they each have a direct linear relationship with temperature. Canada uses 18°C to calculate cooling and heating degree hours, but Validator has Fahrenheit embedded in some calculations such as hourly index, so Fahrenheit was used for this analysis.

An example is shown in the table below. In this example, the regression found T_6, relative humidity, heating degree hours, hourly index, and voltage to be significant in predicting load. (T_{72} and cooling degree hours were not significant; temperature is not used in the regression.) An explanation of the progression follows.

Set	Error in kW/cust (%)	ΔT_6 (°F)	ΔRH (%)	HDH (°F)	ΔHI (0-10 scale)	ΔV (%)	Calibrating CVR_f Process		# Pairs
							Round 1 %MW / Outlier	Round 2 %MW / Outlier	
Set 1	5	5.32	128	7.3	2.04	1	1000 / 2	5 / 2	150
Set 2	2.5	2.66	64	3.6	1.02	1	1000 / 2	5 / 2	110
Set 6	**2.4**	**2.50**	**60**	**3.4**	**0.96**	**1**	**1000 / 2**	**5 / 2**	**100**
Set 5	2.2	2.34	56	3.2	0.90	1	1000 / 2	5 / 2	95
Set 4	1.9	2.02	49	2.8	0.78	1	1000 / 2	5 / 2	80
Set 3	1.3	1.38	33	1.90	0.53	1	1000 / 2	5 / 2	68

The first set of parameters was derived from the regression coefficients and designed to produce a maximum of 5% error in the output. This set of parameters found 150 pairs, which is more than needed. In the next set, the error was reduced by half since there were too many pairs, resulting in an error of 2.5% for set 2. (If there were too few pairs at 5%, the error would be double to 10% for set 2.) This resulted in 110 pairs, leaving opportunity to further refine for lower error.

Each subsequent set will either: double the error if there have been too few pairs in every prior set, halve the error if there have been too many pairs in every prior set, or take the midpoint of the two errors that span too many and too few pairs. The error is always rounded to the nearest tenth percent.

For set 3, since both sets 1 and 2 had too many pairs, the error is halved again to 1.25%, rounded to 1.3%. This resulted in 68 pairs, too few. Set 4 takes the midpoint of sets 2 and 3, for an error of 1.9%, resulting in 80 pairs. Set 5 takes the midpoint of sets 2 and 4, for an error of 2.2% with 95 pairs, and finally set 6 takes the midpoint of sets 2 and 5, for an error of 2.4% with 100 pairs.

With at least 100 pairs and the smallest error satisfying that condition, the answer from set 6 is accepted.

The goal is to have at least 100 pairs while minimizing the error in the load prediction. Having a smaller error is preferable to have excess pairs. The final set of pairing constraints is used in a pairing process that scores potential pairs using the regression coefficients as weights of the differences in each predictor. Consider an example where T_6 has a higher regression coefficient than relative humidity. Consider two potential pairs of hours. The differences in predictors are identical except that one pair has a 1° greater difference in T_6, and the other pair has a 1% greater difference in relative humidity. The second pair would be selected, since a 1° difference in T_6 has more effect on load than a 1% difference in relative humidity (a higher coefficient).

Once this process determines the mean CVR factor of all pairs, the results are used the same way pairing results from Validator would be used.

This process is being considered for full automation and inclusion in a future version of EDGE Validator. Until then, DVI can use it for in-house calculations when the existing Validator process is unable to find enough pairs.

Additional Statistical Techniques

DVI's Validator process is still being refined. For this study, additional statistical techniques were applied, including residual analysis, outlier removal (via deleted residuals, leverage points, and highly influential points), stepwise regression, multicollinearity, and Box-Cox transformation. See the CVR Factor section for more information.

- Residual analysis: assess whether observed error appears to be stochastic (random).
- Outliers: check for a small number of observations y_i or predictors x_i that may have a large effect on the regression model (thereby skewing it). If outliers exist, consider removing these points and re-fitting the regression model.
    - Deleted residuals (also called externally standardized residuals): For each observation (y) in our dataset, remove that one observation and calculate the residual with respect to a regression model that is based on all remaining points. That is, the deleted residual = observed value that is omitted – regression estimate, where the regression estimate is based on only the remaining points. Do this for all points (i goes from 1 to n). If the "deleted residual" is large, it indicates that the point that was removed was substantially away from the curve fit through the remaining points, thus it was probably an outlier.
    - Leverage points: leverage calculation helps select points that are unusual in the x-space, i.e., the predictors are unusual.
    - Highly Influential Points (HIP): use Cook's D calculation to find rows of data that are highly influential in determining the regression model. These points are much more influential (in both x and y space) on the model than any other points. Investigate these rows.
- Stepwise regression: automated process to select which variables are predictive of the output.
- Multicollinearity: when two or more predictors (x_i) are highly correlated, regression coefficients may be estimated inaccurately.
- Box-Cox transformation: check whether a transformation may improve the regression model by making the data more normal.

Calculating Energy Savings

Once a CVR factor is determined, it is used to calculate the energy savings across the On period. This process reverses the CVR factor equation with the newly calculated CVR factor to look at the energy saved during each On hour based on the voltage reduction recorded for that hour. Voltage reduction is calculated as the baseline voltage (average voltage during the Off period) minus the hourly voltage for the On hour. (Any voltage increases will have a negative effect on energy savings.)

$$\%\Delta \mathrm{E} = \mathrm{CVR_f} \times \%\Delta \mathrm{V}$$

Using the measured energy that was imported for that hour, the percent change in energy for each hour is converted to a baseline energy for that hour, or the energy (in MWh) that would have been used if CVR were off.

$$\text{Calculated Baseline Energy} = \frac{\text{Measured Energy}}{(1 - \%\Delta \mathrm{E})}$$

Then the calculated baseline energy is summed across the entire On period, and the measured energy is subtracted to calculate the total MWh savings, and then converted to an overall savings percentage.

$$\text{MWh Saved} = \text{Calculated Baseline Energy} - \text{Measured Energy}$$

$$\%\ \text{Energy Savings} = \frac{\text{MWh Saved}}{\text{Calculated Baseline Energy}} \times 100\%$$

This percent savings, along with the MWh measured and saved, are displayed in the Validator user interface.

The weighted percent voltage reduction is then back-calculated using the CVR factor and the energy savings result from Validator. This is different from the %ΔV value in the preceding equations, which is calculated using baseline voltage and measured voltage, without considering CVR factor. The weighted percent voltage reduction is an average voltage reduction weighted by the amount of energy saved. This adjusts for the fact that nodes typically achieve the greatest voltage reduction overnight, when load is low, achieving a larger percent reduction in a smaller quantity of energy.

$$\text{Weighted}\ \%\ \text{Voltage Reduction} = \frac{\%\ \text{Energy Savings}}{\mathrm{CVR_f}}$$

The information in the Methodology section and its subsections is confidential and is provided under non-disclosure agreement.

Data Preparation and Configuration

The analysis was begun in EDGE Validator v1.6.3. Results were not accepted, so DVI used the enhanced Validator process with regression.

Lethbridge provided electrical data from the SCADA historian, converted to hourly averages from the ION system’s 15-minute export. The data included MW and voltage (on 120 volt base). When initial analysis of T2 using substation data did not yield an acceptable result, generation data was provided by the University of Lethbridge to allow calculation of the total load on the lines fed by T2. Generation data was from the university’s ION system and was converted from 15-minute to hourly averages.

Weather data was from Alberta Agriculture and Forestry, for the station named Lethbridge, which is located at the airport. The weather data included dry bulb and wet bulb temperature in Celsius plus pressure and relative humidity, all in hourly time-series. The weather data also included wind speed, but this was not used in the final analysis because the additional constraint only served to reduce the number of pairs found.

DVI prepared CVR status for each hourly interval, using ON for the low weeks and OFF for the high weeks. The total number of meters on each node was used as the customer count.

Hours are excluded from pairing if they are marked for exclusion in the imported data, if the date is marked as a holiday, or if the user manually excludes them due to suspicious data.

Data Cleanup

Before importing the data into Validator, quality control inspections were performed to ensure the data was in the required formats, no significant amounts of data were missing, duplicate data was not present, and all the required data was available.

LEU populated all fields in the weather data, including wet bulb temperature and pressure. Whenever wet bulb and pressure are provided, Validator will calculate relative humidity and ignore the supplied value. This resulted in the exclusion of a large number of hours, likely because of invalid results when using metric units in an equation written for English units. Further investigation is needed, but the issue was resolved here by removing wet bulb and pressure, and just using the relative humidity from Alberta Agriculture and Forestry. Wind data was not used in the analysis, in order to maximize the possible pairs.

DVI's project team had worked with Lethbridge to prepare weather data with temperatures in Celsius; DVI later determined that Fahrenheit is required, because 65° is embedded in the heating/cooling degree hour calculation in Validator's hourly index feature. DVI plans to add metric support in a future version of Validator. For this study, DVI converted the temperature data to Fahrenheit.

After the inspection and cleanup process, DVI performed the scrubbing process prescribed in the M&V Process flow chart.

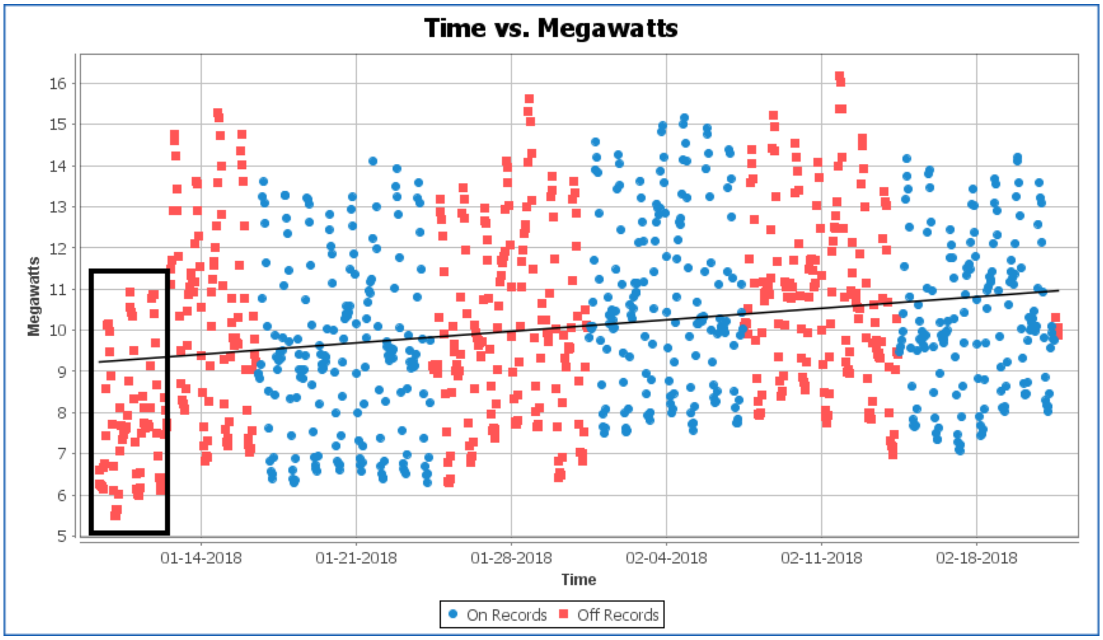
Configuration

The pairing process uses the *hourly index* (described in the Methodology section) to classify the 168 hours of the week based on their non-weather-driven loading characteristics. This obviates the need for limiting pairing by weekday or weekend status. However, Validator does exclude any holidays configured. The configuration included the only statutory holiday that occurred during this period, Alberta Family Day.

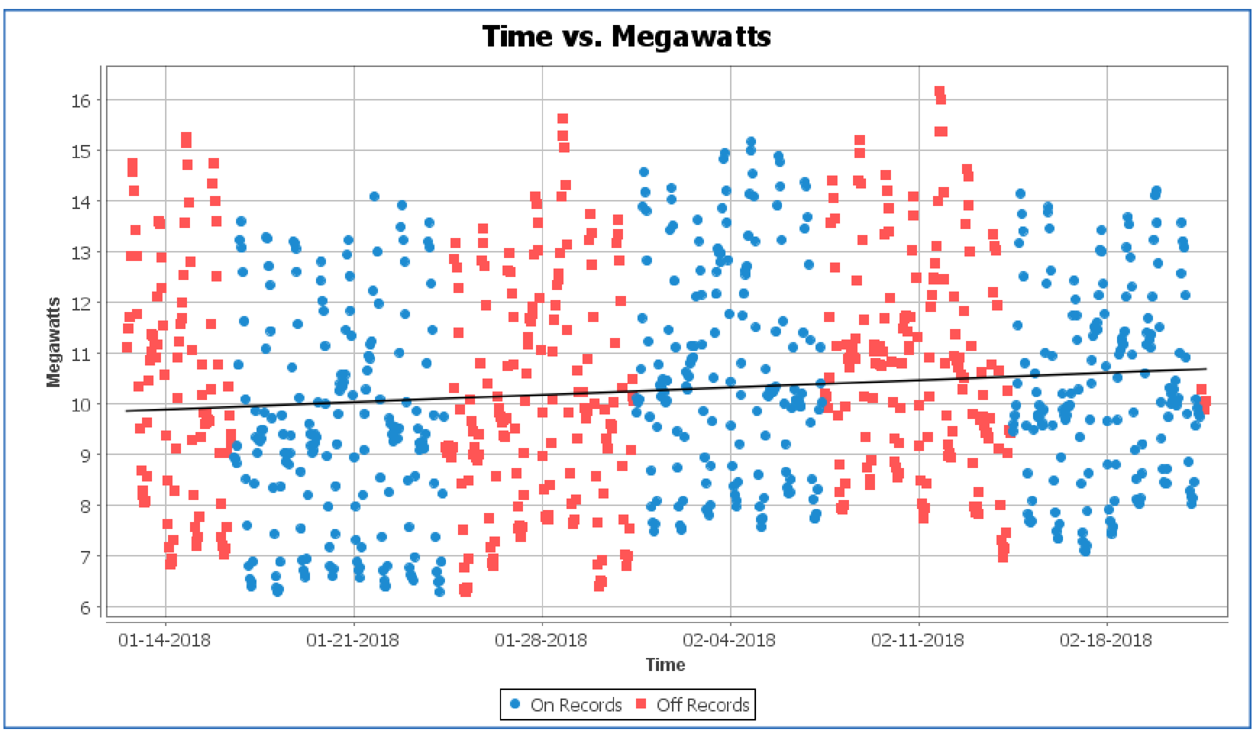
Results

Analysis of High-Low Period

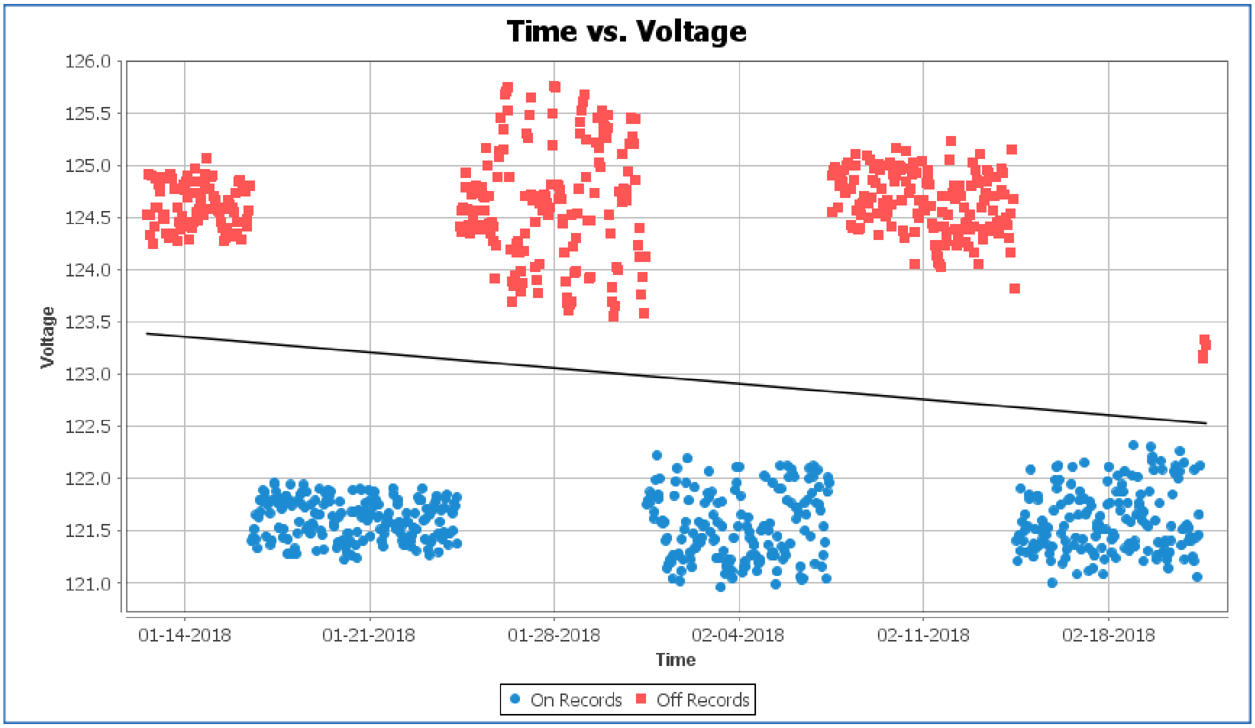
Load data for T1 showed a period of lower load at the start of the study that set it apart from the rest of the period.



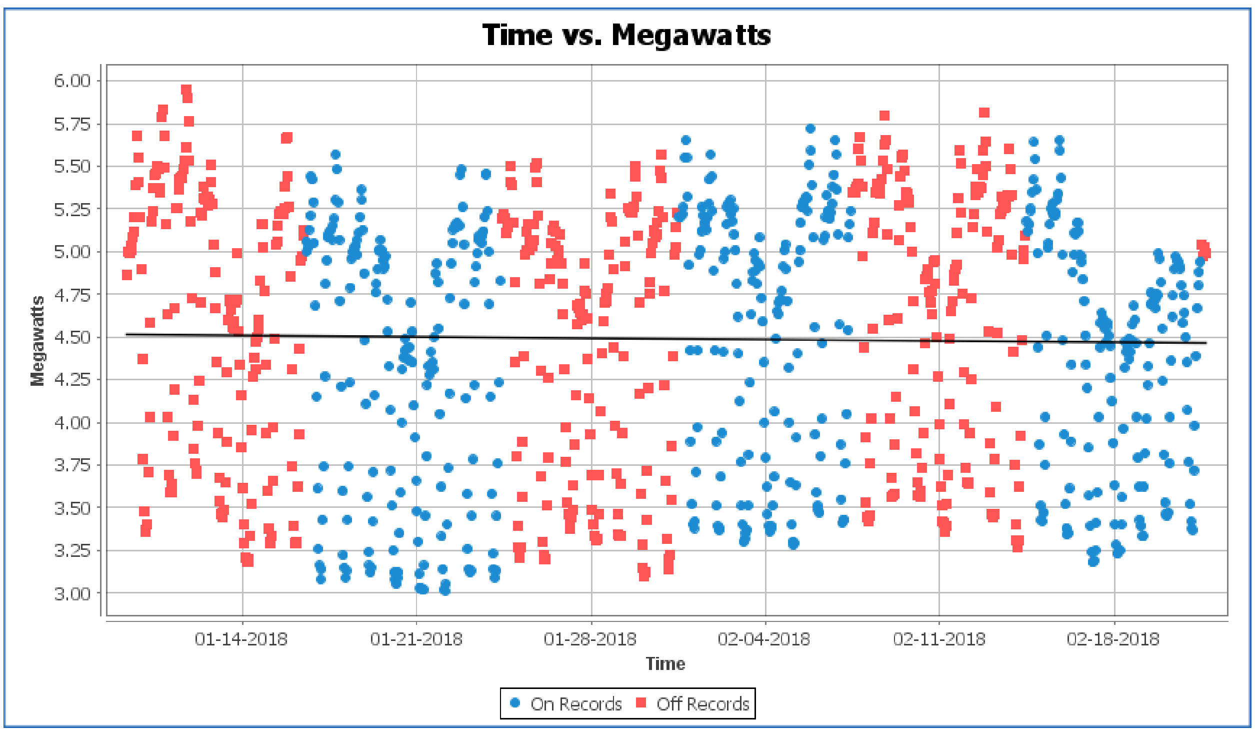
Therefore, the analysis period was configured to start on 12 January at 14:00, leaving the following data.



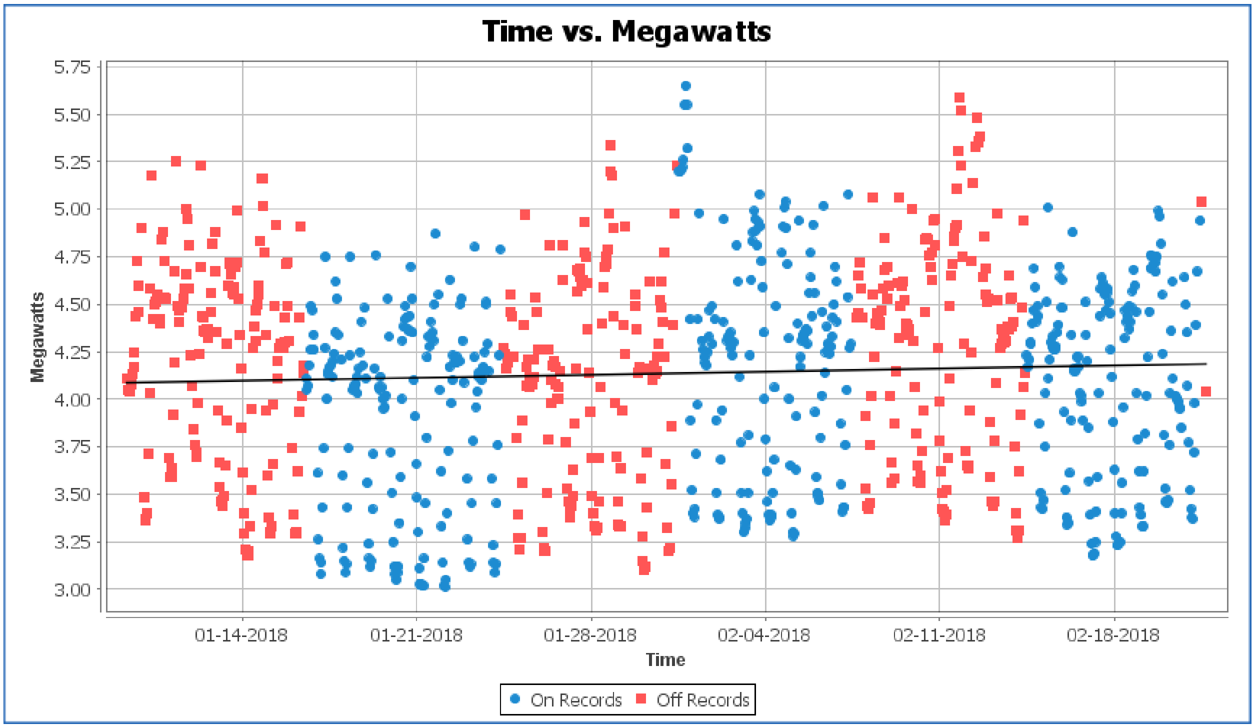
Good separation of the voltage was available between the high and low periods.



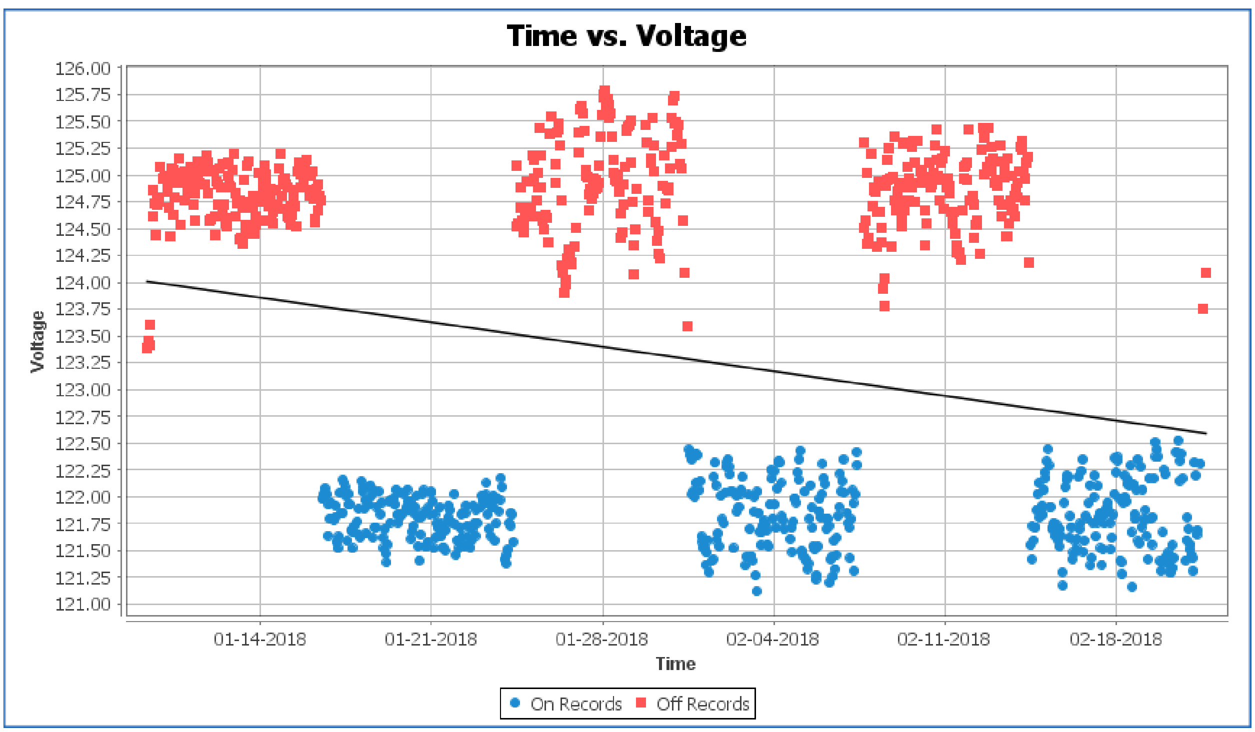
T2 did not show the same lower load period at the beginning, so the entire period was included.



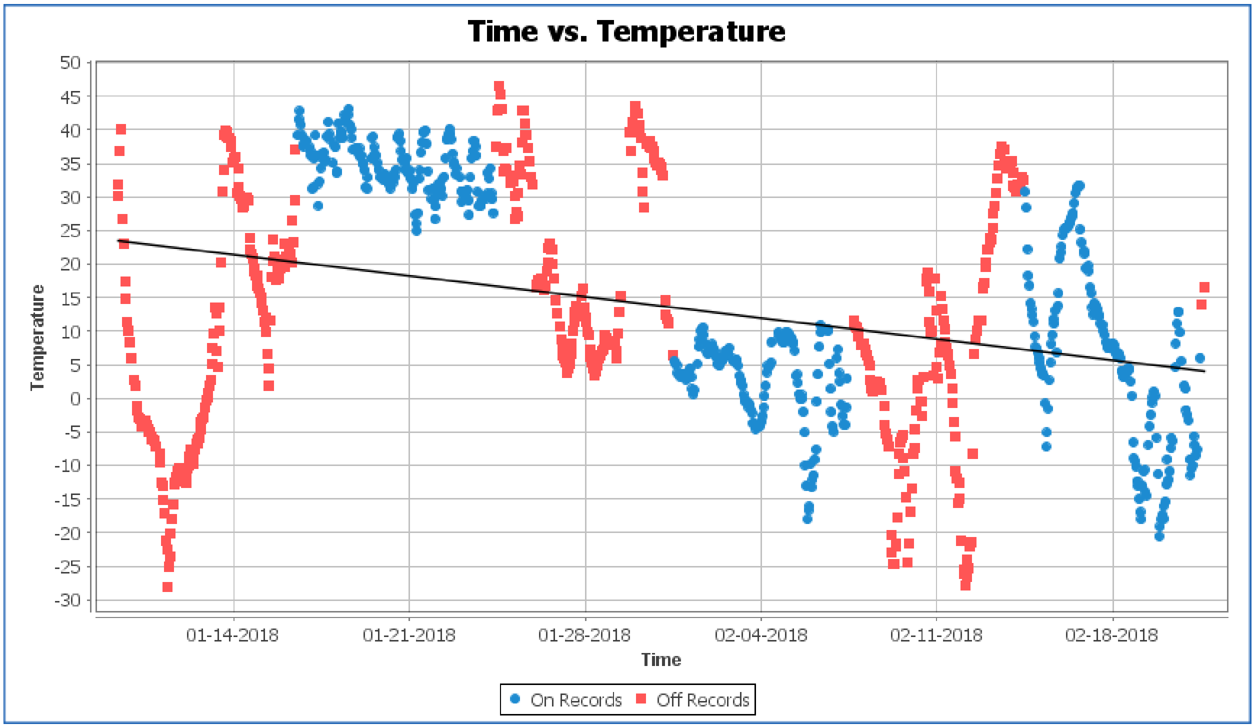
For comparison, the next graph shows the load recorded at the substation, **excluding generation at the University.** Note the spikes that likely reflect days where the generation was out of service.



T2 also showed good voltage separation between high and low.



Temperature (°F) showed inconsistent patterns.



Pairing Constraints

Using temperature in Fahrenheit, the standard sets of pairing parameters in Validator 1.6.3 did not produce sufficient pairs. Therefore, DVI used the new Validator process that incorporates a regression model to identify significant parameters.

On T1, the regression showed that voltage was not a significant predictor of load for the analysis period. This means that variation in load could be statistically explained using weather and hourly index, and did *not* depend on the voltage level in a predictable manner. This means that a CVR factor could not be calculated, since the regression model showed no statistical relationship between voltage and load. This does not mean that no relationship exists, only that it could not be isolated by the regression. For example, voltage and temperature may be confounded based on how the high and low voltage periods fit into the temperature variations.

For T2, the regression successfully calculated a CVR factor. The set of significant predictors for T2 is given in the table below. As described in the methodology section, the regression equation (with the coefficients given in the table below) is used to determine the variation in each predictor that will allow a given error percentage while generating just over 100 pairs. The constraint for each predictor is given in the table below.

The pairing constraints in the table below are the values used for the final result. Cooling degree hours were always zero and were therefore not significant. Heating degree hours were collinear with T_6 (average temperature of the past 6 hours), so T_6 was kept because it resulted in a better $R^2_{adjusted}$.

T2	T_6	T_{72}	Hourly Index	Relative Humidity	Voltage
Regression Coefficient	0.000004	0.000005	0.000228	0.000003	0.000025
Allowed Variation (filter) at 0.8% error/variable	8.132	6.5056	0.142667	10.84267	Fixed at 1

CVR Factor

The results of the analysis are summarized in the table below.

Node	Season	# Pairs	CVR_f	σ	p-value	95% Confidence
674S T1	Winter	-	-	-	-	-
674S T2	Winter	120	0.92	0.85	0.0000	0.77 – 1.07

The data set for T1 did not show a significant relationship between voltage and load (i.e., the regression did not keep voltage as an independent variable), so no CVR factor could be calculated.

Energy Savings

Using the calculated CVR factor for the high-low study, the energy savings during the low periods were calculated as follows. The pre-CVR set point of 123.5 volts was used as the baseline voltage for calculating voltage reduction and energy savings. The CVR factor for T2 was used to calculate energy savings for T1.

Node	Season	Dates	CVR_f	Voltage Reduction (%)	Energy Savings (%)	Energy Savings (MWh)
674S T1	winter	16 Jan – 21 Feb	0.92	1.54%	1.42%	76.03
674S T2	winter	16 Jan – 21 Feb	0.92	1.36%	1.25%	29.08

As described in the Methodology section, the weighted voltage reduction percentage is calculated from the CVR factor and the total energy savings percentage.

Note that these results are not predictive of energy savings from CVR with AMI feedback. This high-low study analysis used a fixed low-voltage set point, and CVR will have varying voltage reduction based on meter voltages. T2 is expected to achieve significantly better voltage reduction than T1.

VALIDATE

High-Low Study Report

Prepared for the City of Lethbridge Electric Utility

9 November 2018

Contents

Executive Summary

This measurement and verification (M&V) performance report summarizes the City of Lethbridge Electric Utility's (LEU) voltage control performance for station transformers **674S T1** and **674S T2** during six weeks in the summer of 2018. DVI used **EDGE® VALIDATOR** software to calculate the energy savings recorded over a period of time when **EDGE® MANAGER** was operating CVR on the pilot nodes. With the goal of obtaining a statistically valid result, the project included a concentrated study period in which the voltage on a node was varied between a high and low voltage set point or band-center. The high-low study was performed on the two substation transformers in the scope of the project. Station transformers **674S T1** and **674S T2** were controlled and examined at defined periods during the summer project using fixed set points on LTCs and regulators.

Determining savings performance requires a series of calculations to generate a statistically sound energy savings estimate. The first calculation is the average conservation voltage reduction factor (CVR factor or CVR_f), which is the percent change in energy for each percent change in voltage.

$$\mathrm{CVR_f} = \frac{\%\Delta \mathrm{E}}{\%\Delta \mathrm{V}}$$

The CVR factor is calculated through a parameterized pairing process that matches an hour from the low voltage periods to an hour from the high voltage periods. The change in energy and change in voltage are calculated for each pair to calculate the pair's CVR_f. The average CVR_f is taken as the resulting CVR_f for that node in that particular season.

The City of Lethbridge provided station data for the period of **16 July – 2 September** for the **674S T1** and **674S T2** nodes during the summer loading season. This analysis gave specific consideration to the **674S T2** node in order to address the on-site distributed generation sources located at the University of Lethbridge. To assist with the total load calculation on customer served by **674S T2**, LEU provided the generation data which was synchronously added to the substation load during those same generation hours.

The data for both **T1** and **T2** shows a statistically significant relationship between voltage and load. The calculated CVR factors are given in the table below.

Node	Season	# Pairs	CVR_f	σ	95% Confidence
674S T1	Summer	78	0.90	1.08	0.66 - 1.14
674S T2	Summer	82	0.83	0.98	0.62 - 1.00

With the table below, the calculated energy savings during the low periods represent what savings may be available during voltage control operation during the summer. Each CVR factor was used to calculate energy savings for both **674S T1** and **674S T2** respectively using the baseline voltage during high state hours. In contrast to the fixed set points of the high-low study, EDGE will lower the voltage at much as possible based on feedback from AMI bellwether meters.

Node	Season	Dates	CVR_f	Voltage Reduction (%)	Energy Savings (%)	Energy Savings (MWh)
674S T1	Summer	16 Jul – 2 Sept	0.90	2.42%	2.19%	79.37
674S T2	Summer	16 Jul – 2 Sept	0.83	2.47%	2.05%	39.43

General Study Approach

The general approach to this study includes the sequential steps of data collection, clean up, preparation, and configuration. Greater detail for each of these steps follows below.

Data Requirements

EDGE® VALIDATOR uses 4 types of data for its analysis.

- Electrical observation data – *hourly substation-level power and voltage*
- Weather data – *hourly temperature, relative humidity, and user-selected variables for a weather station located near the node*
- CVR status data – *the CVR On/Off status, exported from EDGE Manager*
- Customer count data – *the number of customers on the node at different historical dates, used to normalize load per customer as a method of incorporating new customer growth*

Data Collection

Lethbridge conducted the high-low study during the period **16 July – 2 September** during the pilot operating period.

Date Beginning	Voltage	Notes
July 16	High	
July 26	Low	
July 30	High	
August 7	Low	
August 13	High	
August 21	Low	
August 28	High	

The operating parameters for both **674S T1** and **674S T2** were as follows:

Parameter	Value	Notes
Set points for study:		
Low Set Point	121.5	Average set point observed during period
High Set Point	124.5	Average set point observed during period
Bandwidth	6	
SCADA Low Voltage Alarm	no change	Can change if needed
SCADA High Voltage Alarm	no change	Can change if needed
Line Drop Compensation	off	

Data Cleanup

Before importing the data into **EDGE® VALIDATOR**, a visual inspection was performed to ensure all required data was collected, organized in the required formats, confirmed that no significant amounts of data were missing, and duplicative data was not present.

LEU populated all fields in the weather data from Alberta Agriculture and Forestry department weather station, including wind, dry and wet bulb temperature, pressure, and humidity. DVI removed wet bulb and pressure and used the relative humidity data provided for the pairing process. **EDGE® VALIDATOR** did not use wind data for this analysis. DVI converted the temperature data provided to Fahrenheit.

Data Preparation and Configuration

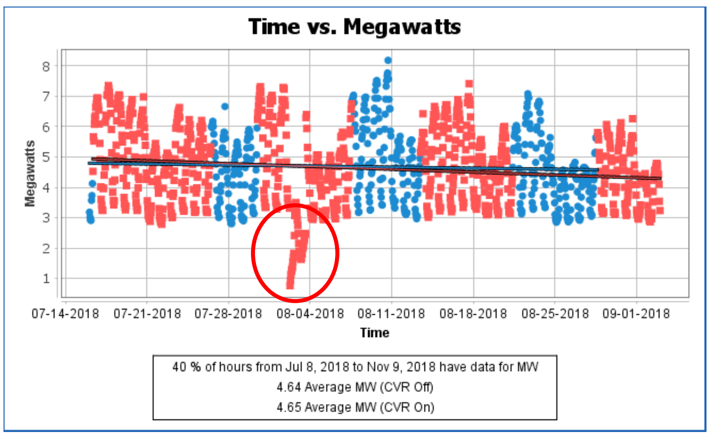
LEU provided electrical data from the SCADA historian and converted to hourly averages from the ION system's 15-minute export. The data included MW and voltage on a120 volt basis. Additional generation data was provided by the University of Lethbridge to allow calculation of the total load on the lines fed by **674S T2**. This data was exported from the University's ION system and converted from 15-minute interval kilowatt readings to an average kilowatt hour over the four intervals. As a test, 1% line loss attributable to the generator was added into the data adjustment to see if the resulting CVR_f was materially affected. It was determined in the analysis that the 1% line loss was not material and it was excluded from the resulting calculations.

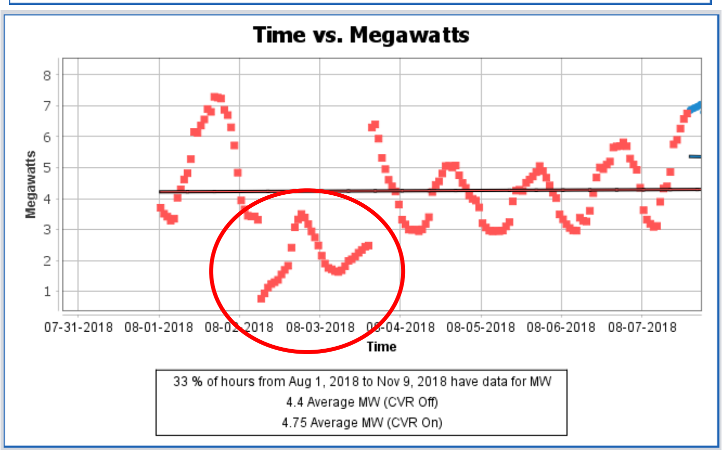
DVI prepared CVR status for each hourly interval, using ON for the low weeks and OFF for the high weeks. The total number of meters on each node was used as the customer count.

Hours are excluded from pairing if they are marked for exclusion in the imported data, if the date is marked as a holiday, or if the user manually excludes them due to suspicious data. Examples of excluded data elements include times with known switching events, excessive voltage differentials, and temporal changes in CVR status when the circuit is transitioning between operational states.

For **674S T1**, LEU provided operational details indicating that this transformer had load moved starting from July 18th. This analysis excludes any pairing activity prior to this date.

In the course of this study, DVI noticed that **674S T2** had some unusual MW data during the August 2nd to August 3rd time period. LEU shared with DVI that some load was moved off **674S T2** from August 2nd from the 5:55 AM to 12:58 PM time period. Based on visual inspection of the time series data below additional data on 3 August was excluded from pairing.





Configuration

The pairing process uses the *hourly index* to classify the 168 hours of the week based on their non-weather-driven loading characteristics. This obviates the need for limiting pairing by weekday or weekend status. However, **EDGE® VALIDATOR** does exclude holidays as configured. Holidays for this analysis period were August 6th and September 3rd.

Analysis Methodology

The information in the Analysis Methodology section and its subsections is confidential and is provided under non-disclosure agreement.

The analysis was started using **EDGE® VALIDATOR** v1.6.3. The M&V tool's goal is to first determine the average CVR factor for a particular EDGE node for a particular season, then use that same CVR factor to calculate the energy savings within that season. An EDGE node is defined as a substation transformer (or set of parallel transformers) and all its downline facilities and meters, and a node's CVR factor is an attribute of the connected loads. Loads may be generally classified by their percentage of constant impedance (square dependence between voltage and load), constant current (linear dependence between voltage and load), and constant power (no dependence between voltage and load). Industry research[1] has studied the voltage dependence of individual appliances. **EDGE® VALIDATOR** calculates the overall CVR factor for the node. Values may vary between nodes, so it's important to calculate it for at least the first few EDGE nodes to understand the range of how a utility's load responds to CVR.

Calculations

CVR Factor

EDGE® VALIDATOR calculates CVR factor using a process that pairs hours from the CVR ON period with hours from the CVR OFF period. The pairing compares the change in a number of measurements found to be significant in their effect on loading:

- Temperature
- Average temperature over the past 6 hours
- Average temperature over the past 72 hours
- Relative humidity
- Hourly index – *a factor calculated by Validator that measures NON-weather-related loading characteristics for each hour of the week, e.g. load at 10 p.m. on Thursday tends to be higher than weather characteristics would predict*
- Megawatts – *used to exclude pairs with large changes in load due to factor other than CVR (such as switching); normalized by customer count*
- Voltage – *used to ensure a minimum change in voltage, to avoid dividing by near-zero in the CVR_f equation*

For all parameters except voltage, the difference between the ON and OFF hours must be *less than or equal to* the configured value in order for the hours to form a pair. For voltage, the difference must be *greater than or equal to* the configured value.

EDGE® VALIDATOR compares every ON hour with every OFF hour based on the configured pairing parameters. All candidate pairs that fall within the parameter limits are given a pairing score, with

[1] K. P. Schneider *et al.*, "Evaluation of Conservation Voltage Reduction (CVR) on a National Level," Pacific Northwest National Laboratory, Richland, WA, Rep. PNNL-19596, Jul. 2010.

smaller differences (e.g. more similar hours and smaller temperature difference) receiving a higher score. **EDGE® VALIDATOR** then selects the pair with the highest score, adds that pair to its collection, and excludes all other candidate pairs that use the same ON and OFF hour as the selected pair. Then it proceeds to select the next highest score. In this way, **EDGE® VALIDATOR** will generate as many pairs as possible such that:

- All pairs meet the specified pairing parameters.
- Each hour belongs to only one pair.
- The highest-scoring pairs are selected first.

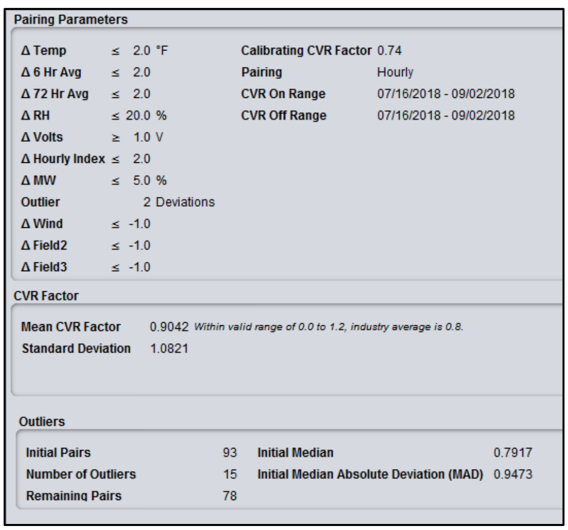
Because **EDGE® VALIDATOR** uses the highest score rather than a randomized pairing order, this method ensures that the same pairing inputs will produce the same results every time the analysis is run.

Once **EDGE® VALIDATOR** has a collection of valid pairs; it will calculate the CVR factor for each pair by dividing the percent change in energy by the percent change in voltage.

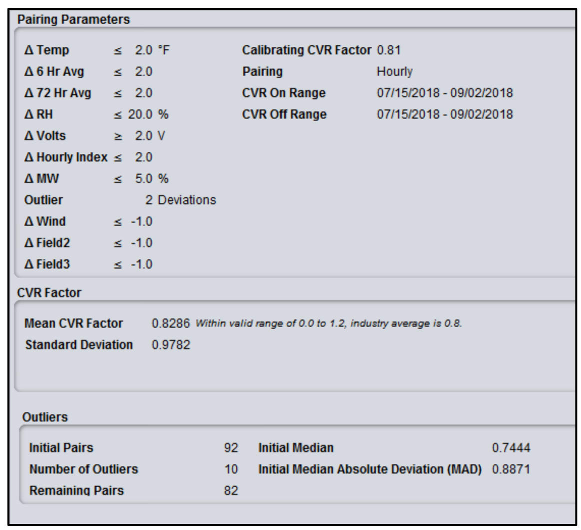
$$\mathrm{CVR_f} = \frac{\%\Delta \mathrm{E}}{\%\Delta \mathrm{V}}$$

At this point, outlier pairs are removed from the population, based on the specified Outlier parameter, which uses the median absolute deviation (MAD). From this final population, the mean CVR factor is calculated and displayed in the **EDGE® VALIDATOR** user interface along with the pairing constraints.

674S T1 Output



674S T2 Output



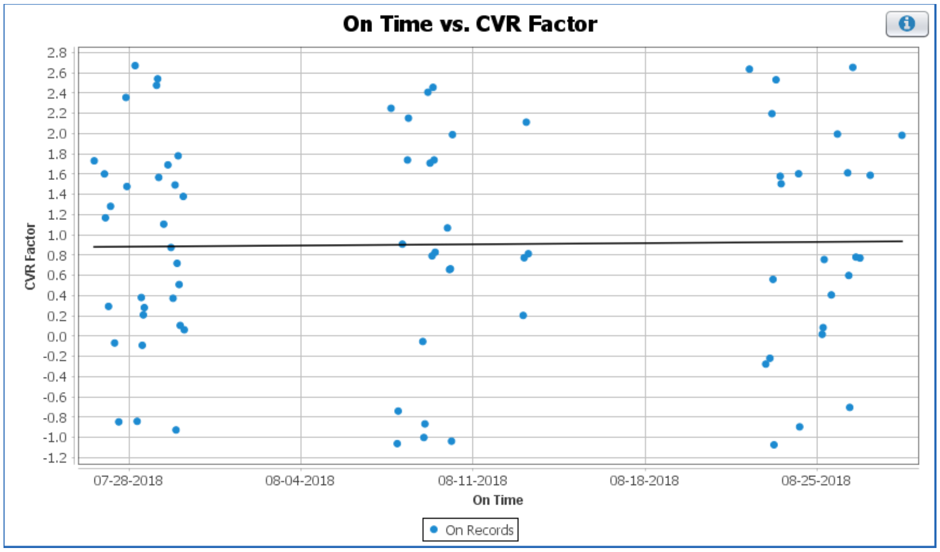
Accepting a CVR Factor Result

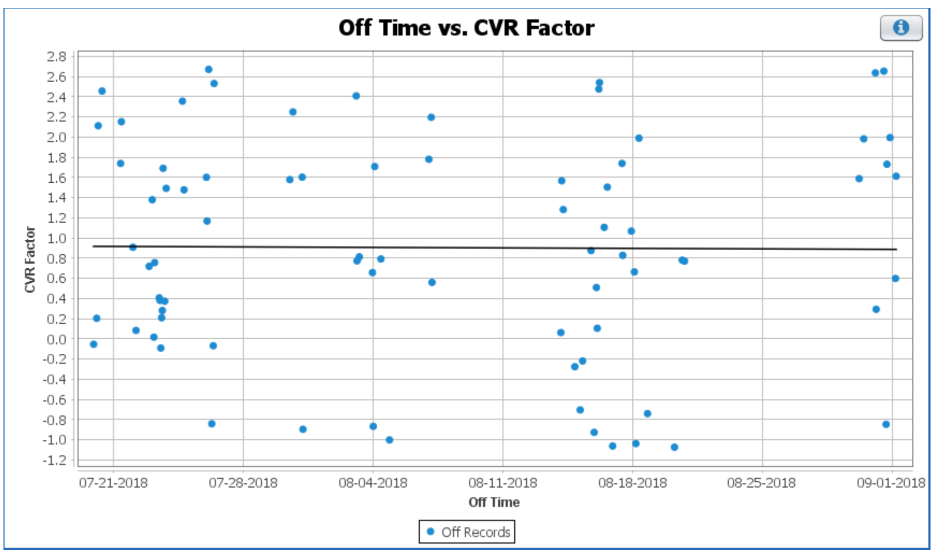
By convention in the statistics field, the minimum number of pairs required is 30, but in DVI's experience, the best results come with populations larger than 30 pairs. Higher pairs often results provide greater representation from all times during the day. Additionally, it is preferred that the standard deviation should not be much larger than the mean.

For this analysis, DVI was able to get 78 and 82 pairs for **674S T1** and **674S T2** respectively.

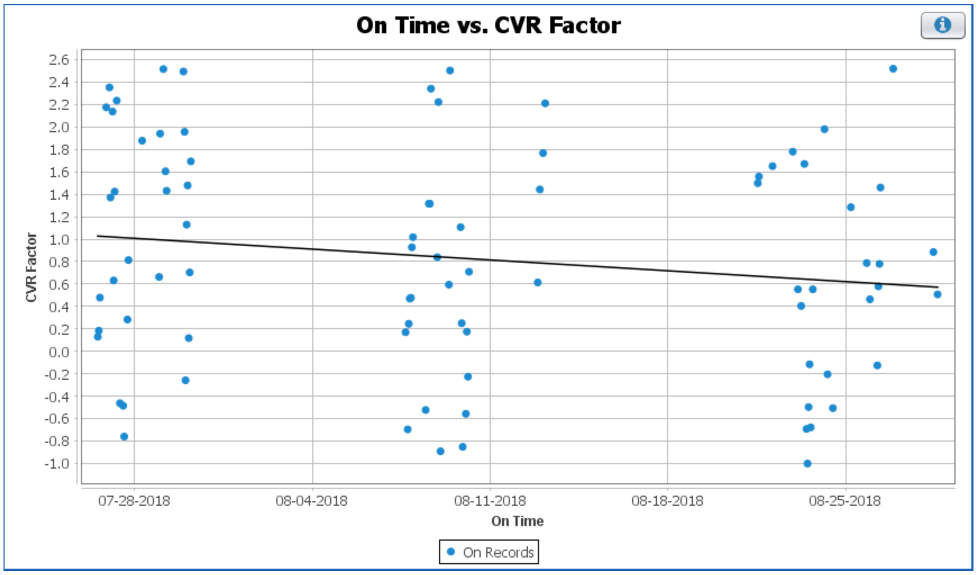
The final step is to visually inspect **EDGE® VALIDATOR**'s graphs of *CVR Factor vs. ON Time* and *CVR Factor vs. OFF Time* to ensure that the trend line should cover less than a 0.5 change in $\mathrm{CVR_f}$ during the analysis period. If the trend is larger than 0.5 then the results are not consistent across the selected time period. To address this inconsistency, adjustments to the start or end dates (or both) may be required the meet the time period consistency requirement.

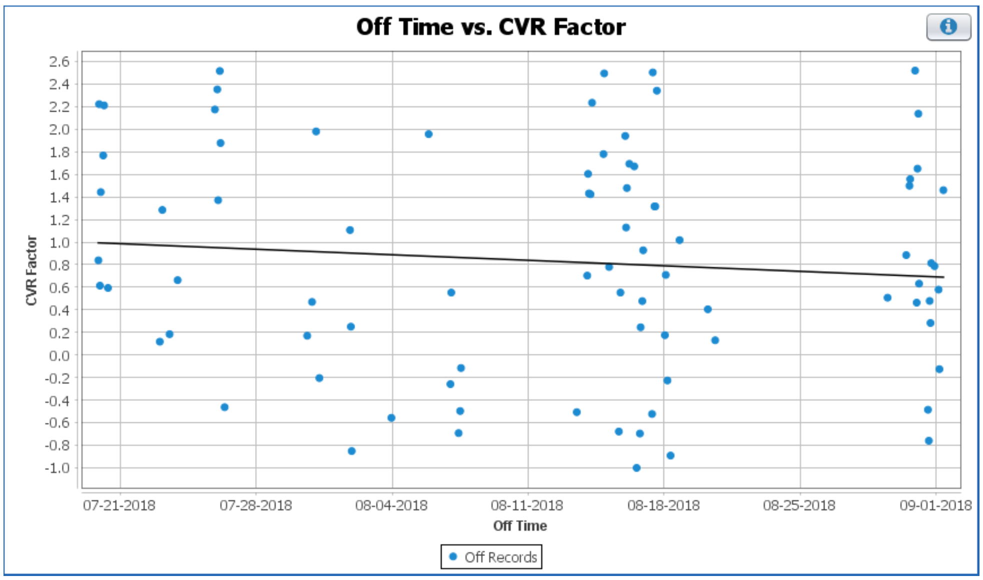
The graphs below for **674S T1** complies with this trend line preference.





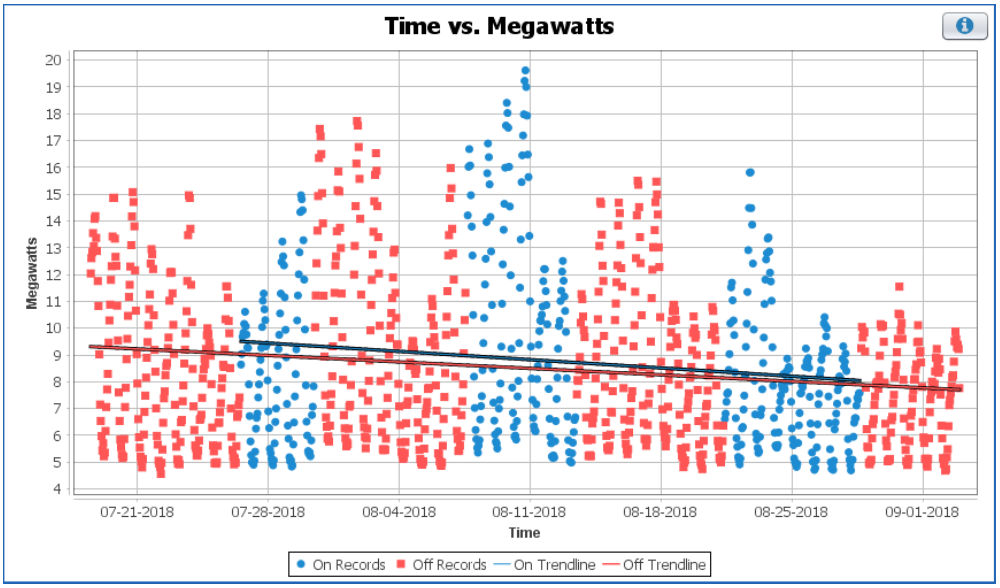
The graphs below for **674S T21** also complies with this trend line preference.



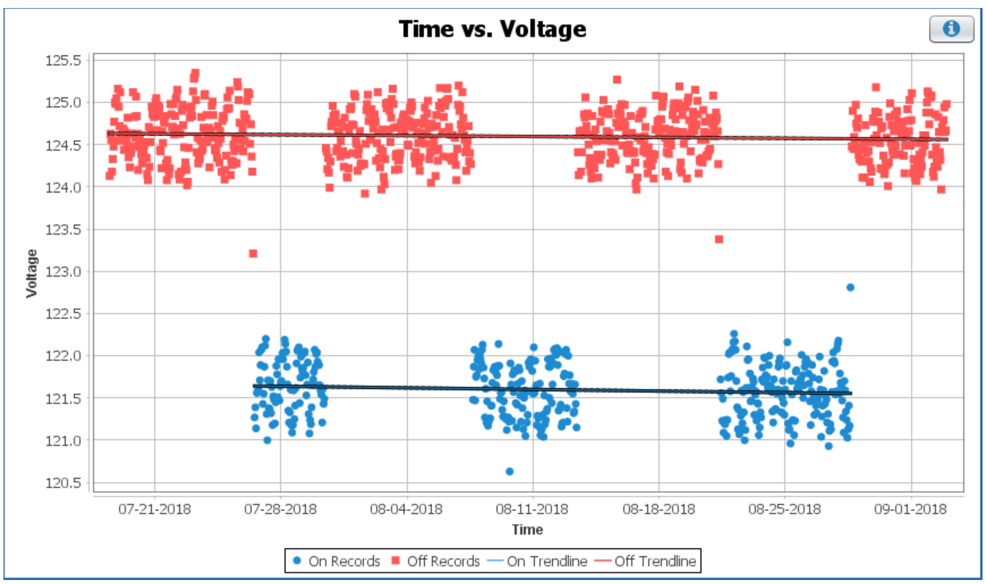


Further Analysis of Accepted Results over High-Low Period

The graph *Time vs. Megawatts* below for **674S T1** below shows the paired megawatt hours over the analysis period.

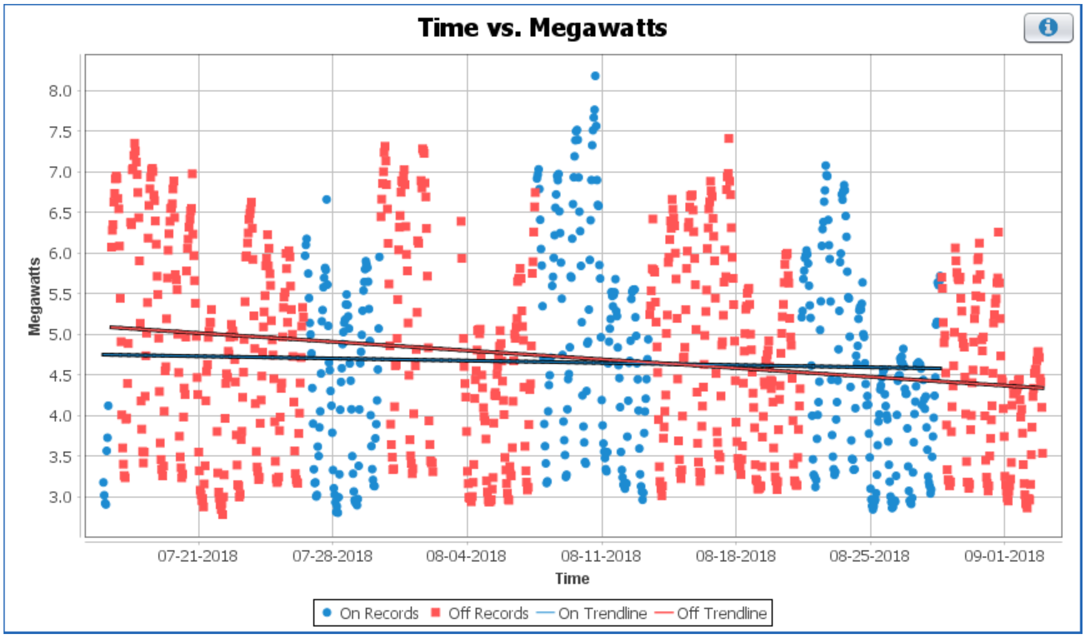


Good separation on **674S T1** of the voltage was available between the high and low periods.

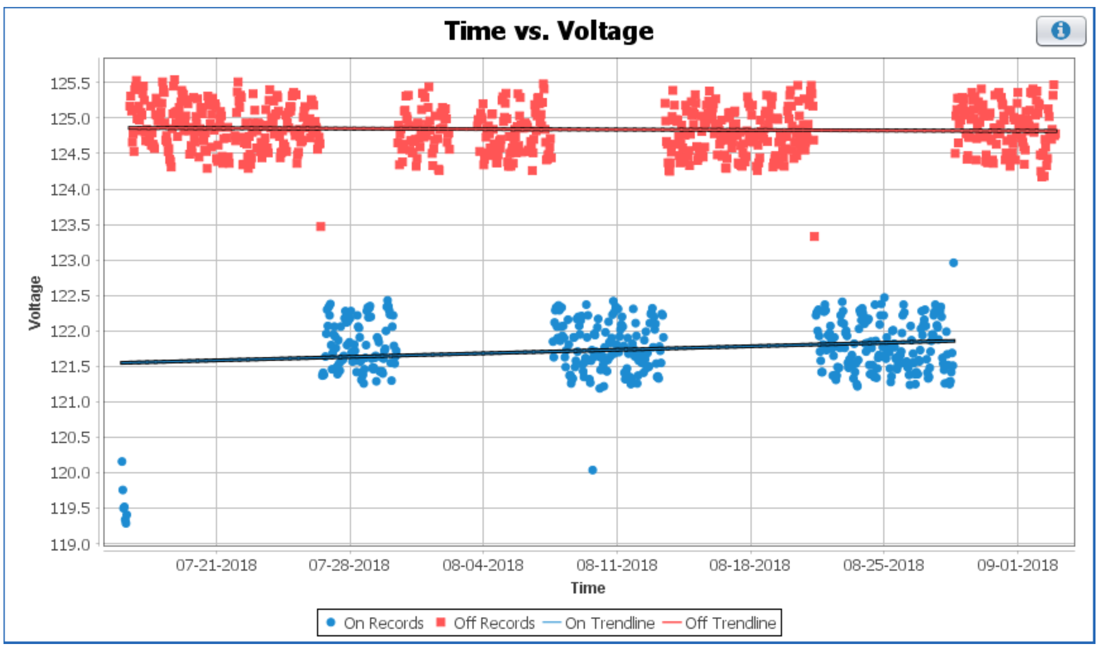


16 July – 2 September

674S T2's *Time vs. Megawatts* graph indicates clean data used for final pairing process.



674S T2's *Time vs. Voltage* graph indicates good voltage separation between high and low operational states.



16 July – 2 September

Calculating Energy Savings

Once a CVR factor is determined, CVR_f is used to calculate the energy savings across the ON period. This process reverses the CVR factor equation with the newly calculated CVR factor to look at the energy saved during each ON hour based on the voltage reduction recorded for that hour. Voltage reduction is calculated as the baseline voltage (average voltage during the OFF period) minus the hourly voltage for the ON hour with any voltage increases will have a negative effect on energy savings.

$$\%\Delta E = CVR_f \times \%\Delta V$$

Using the measured energy that was imported for that hour, the percent change in energy for each hour is converted to a baseline energy for that hour, or the energy (in MWh) that would have been used if CVR were off.

$$\text{Calculated Baseline Energy} = \frac{\text{Measured Energy}}{(1 - \%\Delta E)}$$

Then the calculated baseline energy is summed across the entire ON period, and the measured energy is subtracted to calculate the total MWh savings, and then converted to an overall savings percentage.

$$\text{MWh Saved} = \text{Calculated Baseline Energy} - \text{Measured Energy}$$

$$\%\ \text{Energy Savings} = \frac{\text{MWh Saved}}{\text{Calculated Baseline Energy}} \times 100\%$$

This percent savings, along with the MWh measured and saved, are displayed in the **EDGE® VALIDATOR** user interface.

674S T1 Output

Savings Parameters	
CVR Factor	0.9
Baseline Voltage	124.6
CVR On Range	07/16/2018 - 09/02/2018
Savings	
Usage (MWh)	3,542.11
Savings (MWh)	79.37
Savings	2.19%

674S T2 Output

Savings Parameters	
CVR Factor	0.83
Baseline Voltage	124.84
CVR On Range	07/16/2018 - 09/02/2018
Savings	
Usage (MWh)	1,883.38
Savings (MWh)	39.43
Savings	2.05%

The weighted percent voltage reduction is then back-calculated using the CVR factor and the energy savings result from **EDGE® VALIDATOR**. This is different from the $\%\Delta V$ value in the preceding equations, which is calculated using baseline voltage and measured voltage, without considering CVR factor. The weighted percent voltage reduction is an average voltage reduction weighted by the amount of energy saved. This adjusts for the fact that nodes typically achieve the greatest voltage reduction overnight, when load is low, achieving a larger percent reduction in a smaller quantity of energy.

$$\text{Weighted }\%\ \text{Voltage Reduction} = \frac{\%\ \text{Energy Savings}}{CVR_f}$$

High Low Study Period Results

The results of the analysis are summarized in the table below.

Node	Season	# Pairs	CVR_f	σ	95% Confidence
674S T1	Summer	78	0.90	1.08	0.66 - 1.14
674S T2	Summer	82	0.83	0.98	0.62 - 1.00

Energy Savings

Using the calculated CVR factor for the high-low study, the energy savings during the low periods were calculated as follows:

Node	Season	Dates	CVR_f	Voltage Reduction (%)	Energy Savings (%)	Energy Savings (MWh)
674S T1	Summer	16 Jul – 2 Sept	0.90	2.42%	2.19%	79.37
674S T2	Summer	16 Jul – 2 Sept	0.83	2.47%	2.05%	39.43

To calculate the results over the remaining pilot period, the results of this study and the winter performance report (results provided below) can be used to estimate pilot energy savings. Further analysis and discussion with LEU will be required to determine how to apply winter or summer CVR factors against operational performance experienced over the course of the pilot.

Node	Season	Dates	CVR_f	Voltage Reduction (%)	Energy Savings (%)	Energy Savings (MWh)
674S T1*	Winter	16 Jan – 21 Feb	0.92	1.54%	1.42%	76.03
674S T2	Winter	16 Jan – 21 Feb	0.92	1.36%	1.25%	29.08

* *Winter study CVRf for **674S T1** was inconclusive. CVRf for **674S T2** was used per earlier report.*

PROGRAM SCHEDULE

Friday, May, 4, 2018 at 12:30 p.m.

ELECTRIC GRID OPTIMIZATION MEDIA ANNOUNCEMENT

The event will be held at the City of Lethbridge Electric Operations Building – 208-5 Street North.

Gerald Gauthier will serve as MC and will invite each speaker to come forward during the program. We have allotted 5 minutes for Stew Purkis and 3-4 minutes each for other speakers.

12:30 p.m.	**Gerald Gauthier**, MC Welcome media and provide a quick outline of how the event will unfold (announcement, speakers, scrums/one-on-ones, opportunity to shoot B-roll in the control room)
12:32 p.m.	**Stew Purkis**, Electric Utility Manager for the City of Lethbridge Introduction of guests followed by announcement of grid optimization initiative
12:37 p.m.	**Lethbridge Mayor Chris Spearman**
12:41 p.m.	**Maureen Kolla**, Manager of Clean Power and Heat, Alberta Innovates
12:45 p.m.	**The Honourable Shannon Phillips** Minister of Environment & Parks, Minister Responsible for the Climate Change Office, & MLA-Lethbridge West
12:49 p.m.	**Gerald Gauthier** – Wrap up, outline opportunities to scrum or conduct one-on-one interviews, followed by opportunity for B-roll & photos in the Electric Control Room. Will also mention that Allen Finch can speak to experiences elsewhere in North America where this technology is being used.
12:50 p.m.	Media Interviews
1:05 p.m.	Move to Electric Control Room
1:15 p.m.	Event concludes

NEWS RELEASE

For Immediate Release

May 4, 2018

Lethbridge aiming for greater energy efficiency with new technology, a first in Western Canada

Lethbridge, AB – Lethbridge is the first community in Western Canada to introduce new technology aimed at improving the energy efficiency of its electric distribution grid that delivers power to customers throughout the city.

The City is implementing grid optimization technology, on a trial basis, that safely lowers the operating voltage of the electric distribution system. With this slight lowering of the system voltage, the technology ensures that electricity continues to be delivered to all customers well within national standards set by the Canadian Standards Association (CSA). The expected result will be small energy savings for individual customers that add up to a significant reduction in overall power consumption and demand for the whole system.

"The beauty of this technology is that we expect we can reduce our community's overall power consumption and peak power demand by as much as four percent without the need for residential, commercial and institutional customers to change their behaviour," says Stew Purkis, Electric Utility Manager for the City of Lethbridge. "With full implementation, we expect that could amount to energy savings of up to 33,600 megawatt hours (MWh) of electricity – the equivalent of removing 4,400 homes from the grid."

In 2017, the City of Lethbridge completed the conversion of all electric utility customers to new, more advanced electric meters that provide the utility with a near real-time picture of individual customer and overall peak demand and consumption for electricity in the city. The data provided by the new metering system is required to leverage new grid optimization technologies which can potentially increase grid efficiencies and lower customer bills.

"Lethbridge is being innovative and being a leader in the use of new technology designed to enhance energy efficiency and create savings for customers," says Lethbridge Mayor Chris Spearman.

For the trial, the grid optimization technology is being implemented at one of the city's six electric substations. If the trial is successful, the City will look at deploying the technology across the whole city. Alberta Innovates is a funding partner on this ground-breaking initiative, which utilizes technology developed by Virginia-based Dominion Voltage Inc. (DVI).

“Alberta Innovates is thrilled to be a partner on this smart grid project,” says Maureen Kolla, Manager, Clean Power and Heat for Alberta Innovates. “Innovative projects like this will provide Alberta’s electric distribution companies with the tools to reduce GHG emissions while maintaining safe and reliable electricity for Albertans. This pilot project is the first to be developed and funded as part of the Alberta Smart Grid Consortium. Alberta Innovates, along with the other Consortium partners continue to work collaboratively to accelerate the development and deployment of other smart grid initiatives in Alberta.”

Following is a link to a DVI video that explains the technology in more detail: https://www.youtube.com/watch?v=7uco3UuHbVk&feature=youtu.be.

“It is very rewarding to see an electric utility so passionate about bringing benefits to its customers, to the environment and to their distribution grid,” said Todd Headlee, DVI executive director. “DVI is equally as passionate about working with the Lethbridge Electric Utility to complete this very important project which is likely to be a model for this region in Canada.”

Links:

https://albertainnovates.ca/

http://dvigridsolutions.com/

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Backgrounder:

The Alberta Smart Grid Consortium consists of Alberta Innovates, Alberta Energy and the Alberta Distribution Facility Owners (DFOs), consisting of ATCO, ENMAX, EPCOR, FortisAlberta, Alberta Federation of Rural Electrification Associations (AFREA), EQUS, and the Cities of Lethbridge, Medicine Hat and Red Deer. The purpose of the Consortium is to work collaboratively on projects to accelerate the development and deployment of smart grid initiatives in Alberta.

The City of Lethbridge's CVR pilot project is the first project developed through the Consortium to receive funding from Alberta Innovates. To optimize project outcomes and broadly share project learnings, the Consortium members have formed a technical advisory committee.

Alberta Innovates is a provincially funded corporation with a mandate to deliver 21st-century solutions for the most compelling challenges facing Albertans. We do this by building on our province's research and technology development strengths in the core sectors of health, environment, energy, food and fibre, and platforms such as artificial intelligence, nanotechnology and omics. We are working with our partners to diversify Alberta's economy, improve our environmental performance and enhance the well-being of Albertans through research and innovation.