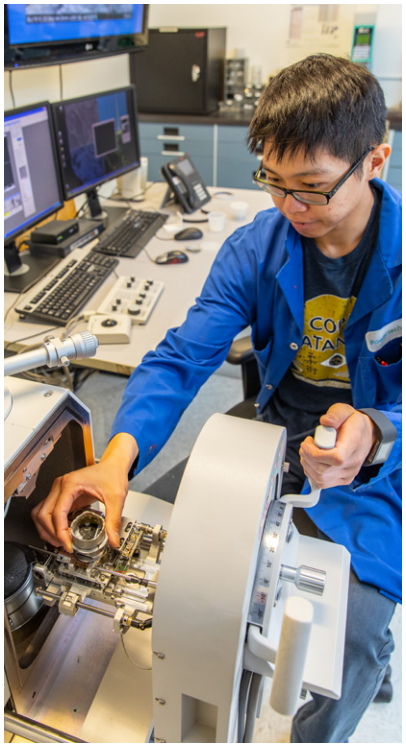
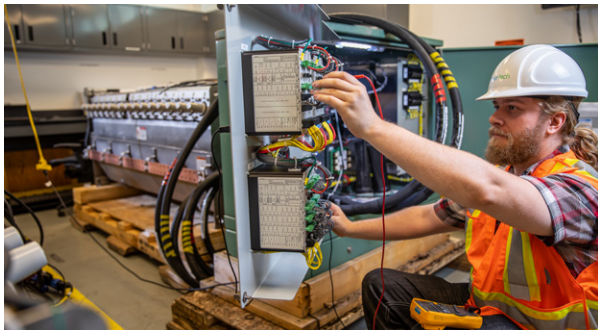
TECHNOLOGY. INNOVATION.

Vol. 2





Powertech

The Power of Trust. **The Future of Energy.**

THE SCIENCE OF INNOVATION

"Powertech has a long and continuing tradition of technical leadership and global "firsts". In 2016, we issued a publication featuring our latest innovations, and I am now proud to present its second edition.

The document you are about to read showcases both the breadth and depth of Powertech's technical prowess. We provide services predominantly to the global power utility and automotive industries, yet our skills and services are also sought by those in other industries such as defense, aeronautics, oil & gas, mining, materials, and manufacturing. We have valued relationships with product developers in these fields, as well as with their customers, industry associations and standards organizations.

As Powertech continues to re-invent the future, we are also expanding. The company has grown significantly over the last five years, and our team of experts now includes around 230 professionals, spanning all engineering disciplines as well as the sciences. Approximately half our staff are technologists and technicians. Powertech also has one of the largest PhD cohorts in British Columbia. Steadily developing new solutions and services to advance the state of the art is in our DNA as a company, as is Powertech's ability to identify and address the safety and technical challenges faced by our clients. We typically find that our newest services tend to be our strongest sources of revenue, with some 15% of our revenue each year coming from new services recently launched. We view this level of return as an endorsement of the value of innovation.

Through our ownership as a wholly owned subsidiary of BC Hydro, and as a key supplier to it, Powertech Labs provides indirect benefits to residents of British Columbia as well as contributes to the leadership position that BC Hydro commands globally. We take pride in being an employer of choice to a highly skilled workforce in our home city of Surrey and in our relationships with the British Columbia province, universities and colleges.

As an applied technology firm, our feet are firmly planted in the real-world: we get our cues for innovation from the industries we serve as well as from the inquiring and critical thinking skills of our staff. To be considered successful, our innovations must be applied in direct support of our customers or squarely address opportunities and challenges in the market. The spark behind these innovations typically starts with us challenging the status quo and imagining a different future. British Columbia has a tradition of environmental stewardship, and so it should not be surprising that many of our new ideas are grounded in clean technology and energy efficiency.

This brochure features some of the new work we are currently pursuing and provides insight into where we think the state of the art is heading. While we are proud of what we are doing and where we have come from, we are driven by the opportunities and challenges still ahead."

- Raymond Lings, President and CEO

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STUDY FOR ENVIRONMENTALLY ACCEPTED INSULATING OILS

Alternative dielectric fluids such as natural- and synthetic-based esters are now commercially available as substitutes for mineral-based oils for transformer applications. Some of their properties appear to have distinct advantages and offer potential benefits in terms of safety, environmental aspects and health, compared with conventional mineral oils.

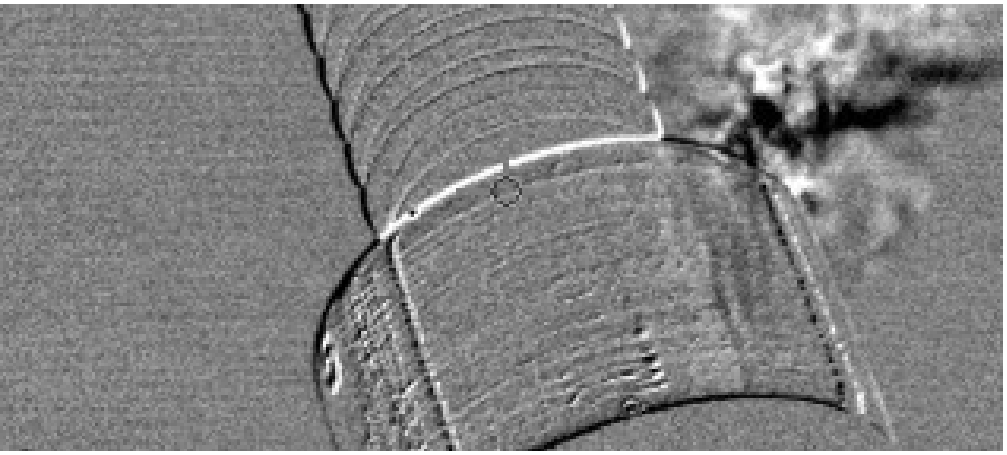
Most of the information available on the market for alternative fluids has been developed solely by manufacturers. Electric utilities needed an independent study to assess the benefits and drawbacks of these fluids or blended oils, including their effects on paper aging under identical conditions, and to assess the long-term performance of the fluids.

Powertech, in collaboration with EPRI, is conducting an in-depth research project to test alternative dielectric fluids for power transformers. Using one-of-a-kind model transformer setups, Powertech can accelerate the ageing of insulating fluids and introduce various faults and operating conditions. The effects of years of ageing under extreme conditions can be achieved on a timescale of weeks or months. These test setups have allowed Powertech to acquire information on the characteristics of the fluids under various conditions, determine established and new degradation product formation, and assess the health of different components in the transformer systems.

ONLINE OIL DECONTAMINATION UNIT (OODU)

As power transformers age, the components and oil also degrade. The degradation products that form can negatively impact the oil quality. Traditional offline transformer oil processing to improve the oil properties requires a transformer to be taken out of service for approximately 5 to 10 days. Taking the transformer out of service may not be feasible without a customer outage and may place the electric system at increased risk of overload or upset. Even if an outage is possible, the cost and coordination associated with offline oil processing may still be prohibitive.

Powertech offers a portable Online Oil Decontamination Unit (OODU) which does not require an outage, operates autonomously, and is a fraction of the cost of offline oil decontamination systems. The OODU uses specialized decontamination cartridges containing proprietary absorbent technologies. As each transformer will have different contaminants due to the different builds and conditions they have experienced, each cartridge type is specific to different contaminants (water, gases, acids, polar compounds, sludge, corrosive sulphur or PCBs). This range of cartridge types provides effective and efficient decontamination, generating only a small amount of waste. With multiple safety features and remote communication, the OODU gives clients the confidence that their asset is protected and that the oil will be enhanced to like-new condition.



SF_6 LEAK DETECTION WITH OPTICAL GAS IMAGING

Sulfur hexafluoride (SF_6) has been listed by the Intergovernmental Panel on Climate Change (IPCC) as a greenhouse gas, with a global warming potential 23,900 times greater than that of CO_2 over a 100-year period. Being a synthetic gas, SF_6 is not absorbed or destroyed naturally, and it can remain active in the atmosphere for up to 3,200 years. SF_6 is used mainly as a gaseous dielectric in gas-insulated switchgear power installations. Currently, electrical utilities consume 80% of the SF_6 produced every year.

Powertech uses state-of-the-art Optical Gas Imaging (OGI) techniques to identify early-stage SF_6 leaks on high voltage substation switching and measuring equipment. Early detection of SF_6 leaks not only reduces the emitted quantity of harmful greenhouse gases but also allows for optimized maintenance activities. Our sophisticated cameras are specifically tuned to a very narrow spectral range, in the order of hundreds of nanometers, and are therefore selective to the particular gas of interest. Since the energy from the gases is very weak, all camera components are optimized to provide a sufficient signal-to-noise ratio by maintaining the filter at a cryogenic temperature. Invisible gases look like smoke through the lens of our OGI equipment, making even the smallest emissions easy to see. Powertech's OGI system can detect not only SF_6, but several other gases, including anhydrous ammonia (NH_3), and ethylene (C_2H_4). Unlike a traditional "sniffer", the OGI allows us to survey large areas quickly and effectively, and inspect spaces that are difficult to reach with non-contact measurement tools.

SF_6 leak detection with OGI techniques provides an additional value proposition, as the observations can be conducted safely without having to take the equipment out of service, allowing leaks to be monitored from several meters away without any violation of limits of approach for the engineers conducting the observations.

Early identification of the leak location and the affected components can significantly reduce repair downtime while minimizing the need for replacement components (e.g. instead of replacing all six bushings on a leaking circuit breaker, only the leaking bushing would be replaced). Conducting annual preventive scans to detect small SF_6 leaks long before low pressure alarms are activated can substantially reduce the emissions of harmful greenhouse gases.

Customers who request this service include operators who need switching equipment conditioning assessments or leak identification following low pressure alarms, and hospitals and sports arenas that use ammonia as a cooling agent.

HYBRID POWER SYSTEM SIMULATION

Traditionally power system study engineers use Electromagnetic Transient (EMT) simulation tools to study the detailed and high frequency transient phenomena of individual components, while use Transient Stability (TS) simulation tools to study the low frequency oscillations of large power systems.

However modern power systems have been undergoing significant changes in the past two decades, which present significant challenges to engineers as their two major simulation tools are facing difficulties in emulating and predicting the behaviors of modern power systems. To tackle this issue, Hybrid Simulation combines the strengths of the two simulation tools and provides power system engineers a new powerful tool to analyze the modern power systems.

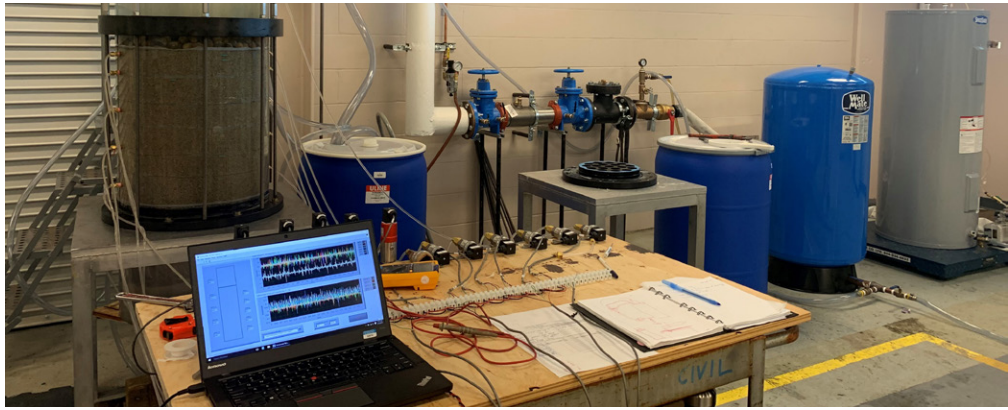
Powertech developed two software modules: TSAT-RTDS®-Interface (TRI) and TSAT-PSCAD®-Interface (TPI), which connect Powertech's powerful TSAT software with widely used EMT simulation tools to perform Hybrid Simulation. TRI is the first commercial grade real-time Hybrid Simulation platform in the world and has been well received by the industry since its inauguration in 2018.

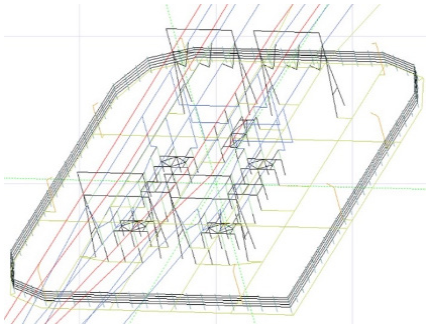
EMBANKMENT DAM GEOTECHNICAL LAB

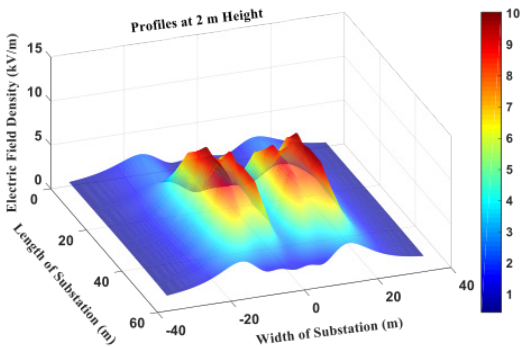
Internal erosion represents a significant risk to the satisfactory performance of embankment dams. It occurs when the hydraulic forces exerted by seepage flow through the pores or cracks of the dam fill are sufficient to overcome the resistance forces and cause particle detachment. Due to challenges with assessing in-situ conditions and a lack of numerical models, internal erosion is typically assessed via non-standardized laboratory tests and empirical methods.

An additional concern is that modern filter design criteria allows for very little erosion of the base material the filter is protecting. Many existing dams do not have a constructed filter zone, or a formal filter that is designed to satisfy modern filter criteria. However, this may not prohibit an embankment dam's primary function, provided that the embankment fill can eventually self-heal after erosion.

Powertech has developed state-of-the-art test equipment to study internal erosion of embankment dam material. Our one-of-a-kind laboratory can evaluate the internal stability and filter compatibility (Continuing Erosion Filter test) of embankment dam material in either a 300-mm diameter permeameter cell (particle size up to 37.5 mm) or a 500-mm diameter permeameter cell (particle size up to 60 mm). We are also developing an apparatus and test methods to assess filtering performance of a cracked filter. The crack-box testing process that we have developed will evaluate the response of a granular filter subjected to a concentrated leak in a large-scale flume device.







INDUCTION 3D MODELLING WITH ELECTRIC AND MAGNETIC FIELD MEASUREMENTS VALIDATION TO REDUCE SAFETY HAZARDS

Electromagnetic fields around high voltage energized conductors induce voltages on any metallic objects located near the transmission lines. These induced voltages can endanger the safety of the general public and field workers in the area. In addition to these safety concerns, induced voltages can cause corrosion on the surface of pipelines, penstocks and railways. In the case of pipelines, if the coating is not strong enough to withstand the excessive stress exerted by induced voltages, this corrosion effect can lead to catastrophic mechanical breakdown. Electromagnetic fields can also cause interference on communication networks.

Powertech has developed sophisticated tools to enhance the safety of the general public and field workers and significantly reduce repair downtime, through early identification of the hot spots within the area influenced by electromagnetic fields. Powertech uses state of the art three-dimensional mathematical modeling software capable of calculating electric field and magnetic field densities in the volume of the system under study, to develop a comprehensive, detailed picture of the electromagnetic effects. To analyze a substation, for example, we can develop a detailed model of the impact of electromagnetic interference from overhead transmission lines on all existing electrical equipment (e.g. circuit breakers, disconnect switches, transformers, insulators). Our three-dimensional modelling is fine-tuned with onsite geographically tagged electric and magnetic field measurements, using advanced portable meters with a 1Hz-400kHz bandwidth that meet the IEC/EN 62110 and IEEE 644 standards for electric and magnetic field measurement.

Powertech uses the IEEE C95.6 standard and best industry practices to determine the permissible thresholds for the electromagnetic field densities. When calculated and measured values exceed the tolerable limits, Powertech can develop mitigation strategies to modify the electromagnetic field profiles.

Customers who request Powertech's 3D modeling service typically include electric utilities, communication companies using transmission towers, and oil and gas pipeline operators.

HIGH VOLTAGE TRANSIENT MEASUREMENTS WITH OPTICAL DEVICES

High voltage transients following equipment switching or balanced and unbalanced faults can involve a rich content of high frequencies. The nature of the transient's frequency response can also be affected by the introduction of passive measuring devices such as inductive or capacitive sensors.

Key attributes of a good high-voltage transient measuring system include safety, accuracy, dynamic range, and representation bandwidth, among other key criteria. Optic sensors provide a significant advantage when used to measure high voltage transients involving a wide-band frequency response including DC. An additional benefit of optic sensors is the galvanic isolation that minimizes electrocution hazards. Current optical instrument transformers are based on Faraday and Pockels effects.

Powertech currently has two mobile optical measuring sets, both composed of a three-phase Optical Voltage Transducer (OVT) and a three-phase Electric Field Sensor (EFS). These sets can be used together or independently, allowing us to measure voltages across circuit breakers, disconnects and transformers, or at up to six different locations on the same phase. Each sensor is equipped with a 200-meter optic fiber to acquire the waveforms at a convenient and safe distance from the measuring point. Our mobile optic voltage transient measurement system operation range is 25kV to 500kV, with a frequency representation bandwidth up to 20kHz. Our optic measuring system can easily be deployed during critical power system equipment commissioning.

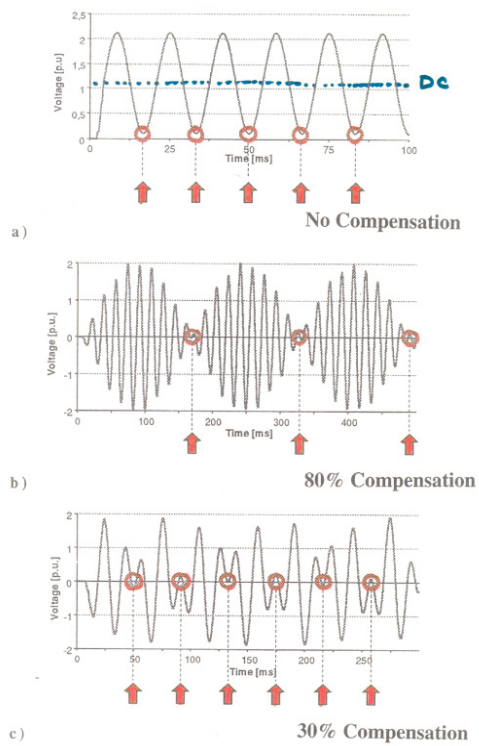
Powertech's engineers can evaluate equipment performance against application requirements. This analysis can be enhanced by transient simulation analysis conducted before the field measurements, which allows us to develop a more effective testing plan by identifying the most critical and practical switching scenarios, as well as predicting the frequency responses.

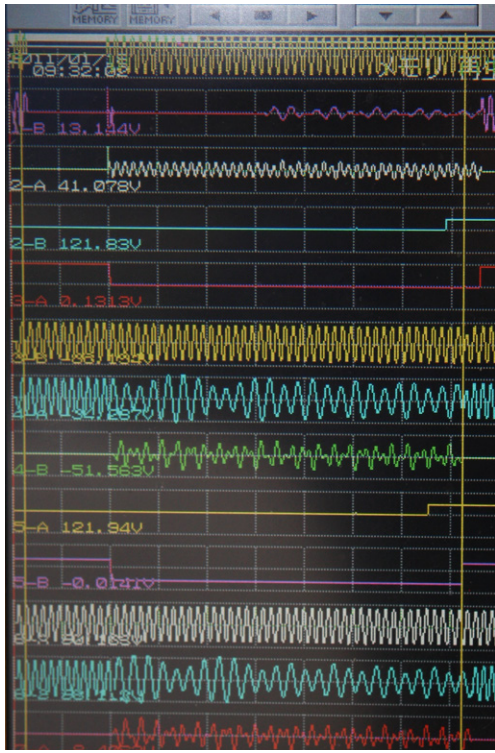
The customers who request this service typically use our measuring devices during commissioning of high-voltage circuit breakers, air- and gas-insulated disconnects, reactor de-energizing, transformer energizing, staged faults, and other similar service procedures.

POINT ON WAVE SWITCHING APPLICATIONS

Random switching of power system equipment may lead to high-frequency over-voltage transient and inrush current. This in turn may stress the equipment, leading to rapid aging or dielectric failure. Point On Wave (POW) controllers, also known as Synchronous Switching Controllers (SSC), are high-speed microprocessor-based relays used to open and close the contacts of independent pole operation (IPO) circuit breakers at the pre-determined point on wave for minimizing the switching transients. The selection of the most convenient point for switching depends on the type of equipment and system configuration. By using this approach, the disturbance to the network and the stresses to the associated equipment can be minimized or even eliminated. Very sophisticated algorithm implementations are available on the market, allowing POW controllers to perform optimum switching of capacitor banks, shunt reactors, power transformers and compensated or uncompensated transmission lines. During protection breaker tripping, the POW controller is bypassed, in order to avoid any intentional introduction of a time delay for fault clearing.

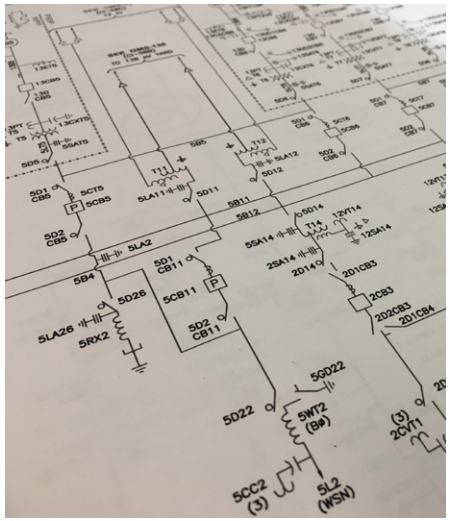
Powertech's team has experience with all major POW controller manufacturers, and we can provide a full range of support services for our clients, including application analysis via EMTP/PSCAD simulation, equipment specification, and POW field performance review. Using state of the art simulation tools, we can model switching transients to assess stresses in terms of inrush currents, re-strikes overvoltages, and TRV online terminal circuit breakers. This modeling allows us to determine the most effective strategy for implementing POW controllers. Our team can produce POW equipment performance specifications based on interconnection requirements and system impact studies that we conduct. We can also review tender bids for POWs and circuit breakers to recommend the best equipment selection, based on the customer's switching applications and the power system configuration.





Our Substations Engineering Studies team can also assist customers during the commissioning phase in developing commissioning and integration testing plans.

The customers who request this service typically use it for controlled reactor de-energizing, capacitor bank energizing, power transformer switching, transmission line energizing, and single pole reclosing.



COMPREHENSIVE APPROACH TO STATION PLANNING

Planning a power system is a multilevel process requiring attention to a broad range of issues and details across a wide technical spectrum. Important aspects to be considered include type and size of loads and energy sources, transmission line connections, load flows and dynamic stability studies, voltage stability, transient stresses, and protection and control requirements, including communications. Together, a detailed consideration of these aspects helps to achieve a cost-effective station plan, with outputs that include station planning one-lines and equipment specification sheets.

Powertech's comprehensive approach to station planning includes the following suite of services: station topology definition; station transformation; station studies such as short-circuit, load-flow and transients; equipment specification; and implementation staging.

Selecting the appropriate station topology is a multidimensional exercise that must include, at a minimum, consideration of reliability, security, maintainability, construction and operation costs, operability, familiarity to customer's staff, environmental regulations, safety, space requirements, and community needs. Powertech's planners define the in-service-day, and required inter-medium and ultimate station topology, considering the planned growth needs of the customer. With the overall topology and development plans of the station over the considered life of the station, our planners define the required specifications for the transformers, including winding configuration, voltage ratios and transformer impedance, tap change needs, and BIL and SIL ratings. These transformer parameters in turn affect the selection of system grounding, switching requirements for circuit breakers and disconnects, and the functional protective logic. In addition, our team considers the most cost-effective approach for component selection, using our extensive experience with the rating structure and standards for transformers, circuit breakers, surge arresters, capacitors, instrument transformers, and other related station equipment.

Our Substations Engineering Studies team can compute initial fault estimates and conduct studies to establish the ultimate and initial fault levels. We can also perform special transient studies to identify temporary and power frequency over-voltages, and develop mitigation measures to achieve a proper insulation coordination that meets switching and lightning requirements. Once the concept and system performance issues are studied, our planners can capture the concept in a simple conceptual one-line diagram. Our team can then develop the associated station specification sheet wherein the required ratings of each piece of equipment are recorded for input into the customer's design and equipment procurement processes.

Our station planning product gives our customers the benefit of Powertech's unmatched, in-depth knowledge of all aspects of station planning.

HYDROGEN FUELING STATION IN A BOX

Hydrogen fuel cell vehicles are becoming increasingly popular as an alternative to gasoline and diesel vehicles.

To support this growing industry, Powertech has developed a novel 70 MPa "hydrogen station in a box" designed for rapid deployment of hydrogen fueling infrastructure. This design offers a compact footprint with minimal site preparation and installation, allowing station owners to quickly and easily provide fueling infrastructure to support new fleets of alternative fuel vehicles.

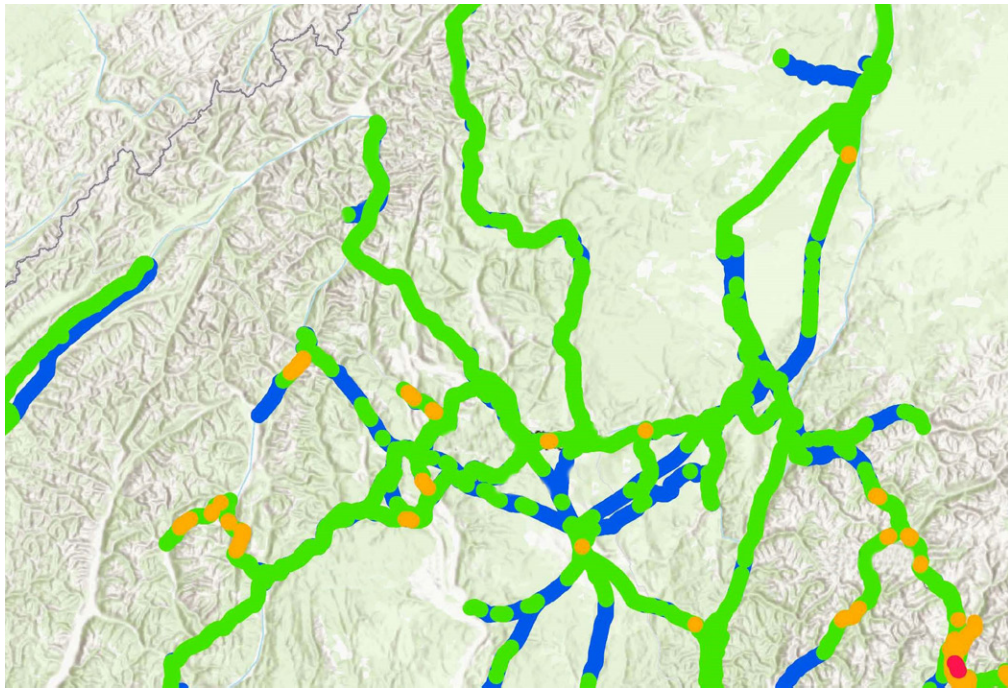
The station can deliver four consecutive fills of a typical passenger vehicle and is sized to fill approximately 20 vehicles per day. Station features include a payment system for credit and debit cards, a single-hose dispenser with touch-screen user interface, and a control system with remote access capability for monitoring the station, managing station faults, and downloading station data.

All components, including storage, compression, cooling and dispensing, are enclosed in a 28-foot containerized package. This single-container concept allows the station owner to easily transport the equipment from site to site as needed. The design also substantially reduces site preparation time and cost, as the station can be dropped at any suitable location and requires just a power supply and a hydrogen source. This design is ideal for temporary installations, or a mother-daughter setup for geographical areas that are just beginning to enter the fuel cell market and need to provide quick, simple and lower-cost solutions.

MODELING OF CORROSION RISK

BC Hydro has over 20,000 metal structures that are subject to corrosion attack from both overhead and underground. Corrosion-induced damage or failure can result in extended forced outages, and represents risks in terms of reliability, safety and cost. Since 2012, a capital program has been in place to mitigate the corrosion risk across the province, and there has been a need to identify and prioritize the circuits and structures at high risk, for application of the corrosion mitigation program.

In 2019, Powertech started a comprehensive system corrosion study for BC Hydro, with the goal of developing a model to generate a qualitative assessment of relative corrosion risk, using available data and corrosion science. This model was validated and calibrated by field verification and has been used to prioritize the highest risk transmission circuits and structures. We also developed geographic information system (GIS)–based datasets for use in the corrosion model.



MODEL DEVELOPMENT FOR ELECTRIC POWER SYSTEM LOADS

When industrial loads such as electric furnaces or aluminum smelters are interconnected with an electric grid, their transient and dynamic behavior can have a significant impact on grid operation, especially for a weak system. Unintended tripping of such loads can not only cause major interruption of industrial production but may also result in cascading events on the power system and lead to power outages in the interconnected system.

Grid codes and reliability standards stipulate technical requirements for grid-interconnected industrial loads and generators. Industrial customers are responsible for developing valid simulation models for their production facilities, to be used for power system planning and operation studies. Industrial customers are also responsible for ensuring that harmonics produced from industrial facilities do not exceed permissible limits set by the grid codes and standards – customers must be prepared to install well-designed and tuned harmonic filters to prevent harmonics from penetrating into the grids and causing inadvertent tripping or damage to electric power equipment. The task of developing accurate models for large industrial production processes and massive air-conditioning loads is especially critical to prevent system blackout due to voltage instability or Fault-Induced Delayed Voltage Recovery (FIDVR).

To meet our customers' needs, Powertech offers comprehensive modeling services for transmission-connected industrial loads and distribution-connected commercial and residential loads. Powertech performs model development for industrial loads through staged field tests or system events. We have successfully completed several load modeling projects for industrial plants that utilize electric arc furnaces and aluminum smelters.

Powertech also provides services in developing more complex load models, such as composite load models for distribution systems, using data analytics, surveys and/or event recordings, to address the FIDVR issue and other challenges in the operation and planning of present-day power systems.

FIELD MONITORING OF HIGH VOLTAGE CABLES DURING CONSTRUCTION

Buried high-voltage transmission line cables are often located near infrastructure that requires construction activities. Utilities need real-time information on construction-induced ground movement and vibrations, to support allowing construction to proceed near buried cables, while avoiding the need to de-energize the circuit.

Powertech has developed a cable field-monitoring system that is typically mounted directly on the cables after the utility has provided access. This field monitoring system consists of sensors, power supplies and cellular real-time monitoring.

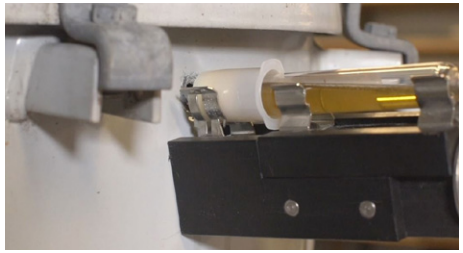
Our system continuously monitors cable ground movement and triggers warnings to the construction site and utility. These real-time warnings ensure that construction activities are stopped before costly damage and/or significant customer outage occurs. Additionally, the ground movement data can be used by utilities to refine construction guidelines near buried infrastructure, in order to streamline permitting.

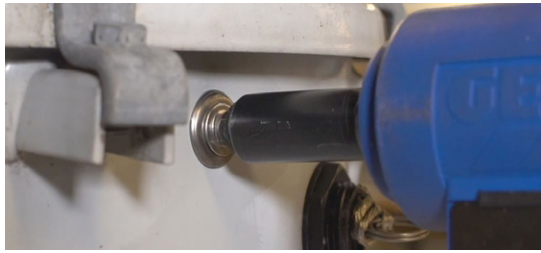
PCB OIL SAMPLING FOR POLE TOP TRANSFORMERS

Many utilities around the world have been challenged to comply with Polychlorinated Biphenyl (PCBs) regulations that require removal, by 2025, of any electrical equipment that contains more than 50 parts per million (ppm) (mg/kg).

Among the last and most difficult categories of electrical equipment requiring compliance with these regulations are pole-top transformers. Utilities have typically employed two strategies to meet compliance - wholesale replacement, and oil sampling. Oil sampling, which involves drilling and subsequently sealing a hole in the transformer, has been tainted by past industry practices that can lead to premature failure of the transformer.

Powertech's engineered and extensively field-tested oil sampling system allows for energized sampling without customer interruption or reduction in transformer life. Our system has been used on tens of thousands of transformers since 2017, and has proven to be an efficient and safe method of obtaining oil samples.





TRANSMISSION LINES DATA SERVER (TLDS)

The BC Hydro transmission system stretches over 75,000 hectares throughout the province, including 100,000 wood poles and 22,000 steel towers. Over time, these assets are subject to degradation, corrosion, and electrical and mechanical failure. General maintenance includes inspection of these assets, and inspection quality and accuracy are critical to the decision-making process for timely repair and replacement.

Powertech's Transmission Lines Data Server (TLDS) tool allows field workers to use a mobile app to record asset condition, even from remote locations. Using TLDS, crews can confirm inventory, log each asset's condition and defects, verify maintenance, conduct quality assurance, scan UID tags to confirm GPS coordinates, and take photos as part of overhead and corrosion inspection. Because mobile devices are synced to a data repository, the field data is instantly transferred to office computers, rather than awaiting paper transfer or email.

Engineering staff at the office then review the data, including detailed analysis of photos to determine damage level and maintenance requirements. The increased availability of information, improved data auditing, and faster analysis allow BC Hydro engineers to "make the right decision at the right time" regarding the life cycles of transmission assets.

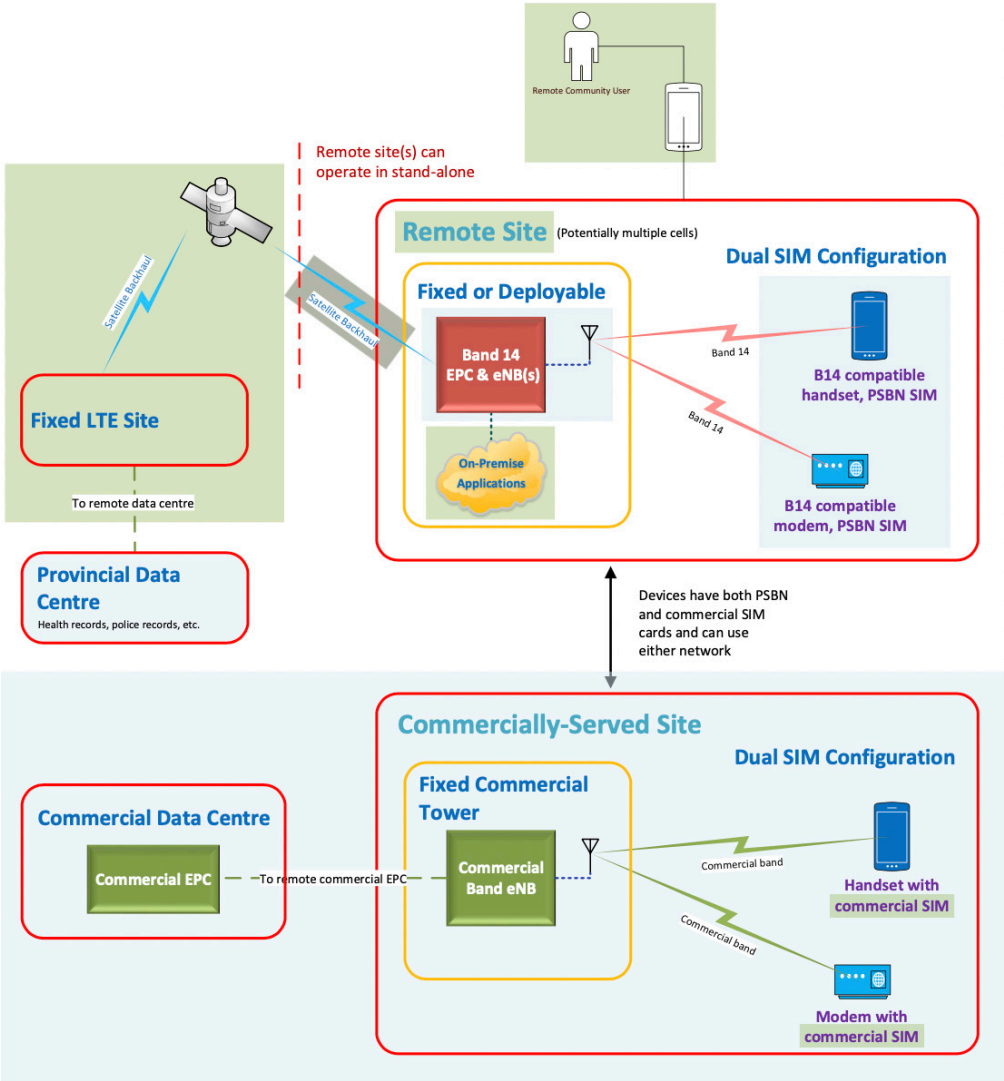
The TLDS tool offers a number of advantages over the previous manual inspection and data transfer process. Switching from paper to electronic inspection helps eliminate human error, data entry is easy and user-friendly, data is entered in a consistent and standardized manner, quality assurance (QA) is built in to the applications, resulting in higher quality data, data from field inspections is immediately transmitted to asset managers, and photos are included with every completed inspection.

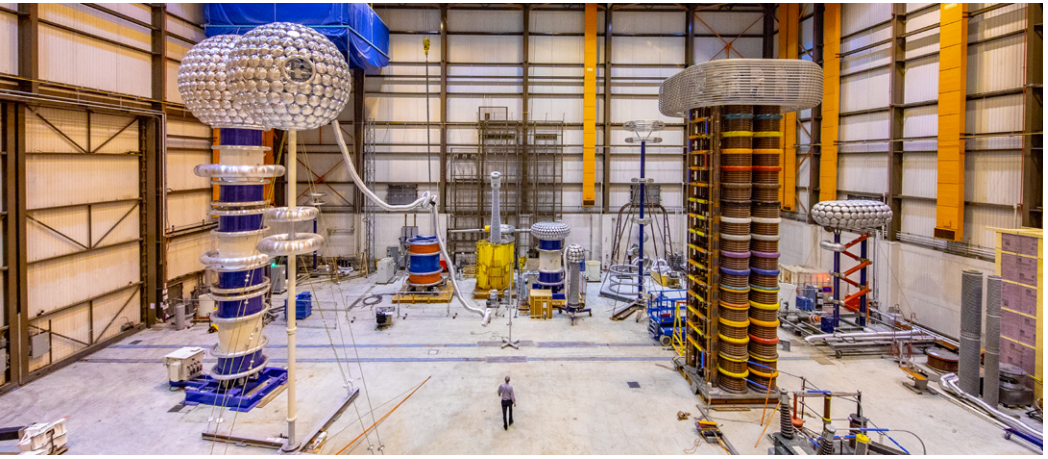
PRIVATE LTE NETWORKS FOR PUBLIC SAFETY AND EMERGENCY MANAGEMENT

In 2007, when television went digital, the Federal government reserved 20MHz of the 700MHz band for public safety, known in 3GPP terms as "band 14". The same spectrum was allocated in the US for public safety. The Federal and Provincial governments, in conjunction with public safety agencies, convened a number of working groups to define the options for governance and deployment models. In 2017, the US started implementing a public safety LTE network across the US, using a combination of their own licensed spectrum and band 14. In May 2018, a meeting of Federal, Provincial and Territorial ministers responsible for emergency management endorsed the use of Public Safety Broadband Network (PSBN) to leverage LTE technologies for emergency management in Canada.

During the current COVID-19 crisis, it became even more apparent that the protection of first responders in current and future health emergencies was critical and needed to be addressed.

Powertech partnered with the Province of BC, E-Comm 911 and several first responder agencies to create an inter-operable, multi-vendor architecture to support an emergency management and crisis response application using LTE networks. This technology is now able to support several solutions for remote area communications, emergency management and multi-agency coordination and pandemic management.





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