

TECHNOLOGY.
INNOVATION.



Powertech

www.powertechlabs.com

The Science of Innovation

At BC Hydro, we're always looking for smarter ways to maintain a reliable system and deliver clean, affordable electricity.

We want to be the most trusted, innovative utility in North America, and leading the way in our efforts to achieve that lofty goal is our own world-renowned testing and research laboratory, Powertech Labs.

A wholly owned subsidiary of BC Hydro, Powertech Labs is made up of about 180 scientists, technicians, engineers, and specialists. They pool their efforts and expertise to support electrical utilities, original equipment manufacturers, and the automotive industries.

"It is difficult to dismiss the innovations coming out of Powertech. It is a large lab of approximately 180 experts in their own field who understand the utility business. This expertise is used to bring changes into the marketplace", says Lings, President & CEO of Powertech Labs.



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In the utility realm, Powertech works on a range of innovations—from how we generate electricity, to how it's used by our customers.

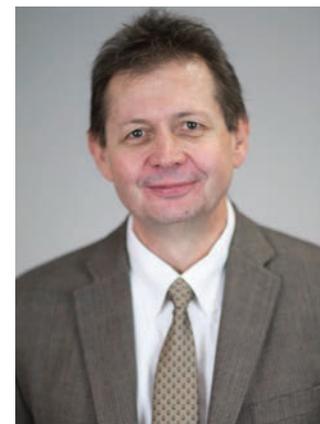
This brochure celebrates innovation—our homegrown ingenuity and its impact on the broader world. By necessity, it's a catalog of "firsts"—ground-breaking research that has changed the way we operate, and solutions that have been adopted by utilities around the globe.

Equally important is that these innovations have provided value for our customers and our employees. It's a value measured in avoided costs, productivity gains, extension of the service life of facilities, enhanced performance, optimized maintenance, and energy efficiency.

The new tools profiled here have made their mark in the real world. They've made utility field work safer, ensured the reliability of grid operations, and cut the costs of energy delivery. And they've reduced environmental impacts while allowing customers to use electricity more efficiently and conveniently.



*Jessica McDonald
President and CEO
BC Hydro
Chair, Powertech Labs*



*Raymond Lings
President and CEO
Powertech Labs*



INNOVATIONS AT A GLANCE



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HyStEP—Hydrogen Fueling Performance

Powertech designed and built the new Hydrogen Station Equipment Performance (HyStEP) device to reduce the commissioning time of new hydrogen fueling stations from an average of several months to just one week.

The device—the first of its kind in North America—ensures public hydrogen refueling stations meet industry standards but does so more efficiently than previously possible. The HyStEP device addresses a key challenge for hydrogen refueling stations. The current commissioning practice for these stations can be time-consuming because each manufacturer of hydrogen vehicles conducts its own validation tests to measure the performance of hydrogen dispensers with respect to fueling protocols. This could delay the commissioning of stations in areas such as California, where new stations are coming online, and as many as 35 new stations are scheduled to be commissioned in 2016. The HyStEP device acts as a surrogate for vehicles, eliminating the need for each automotive manufacturer to test separately. The device connects to a hydrogen station and monitors and evaluates pressure, temperature, and communications data to ensure the station operation and fueling process meets the standard method for compliance with industry protocols.

KEY BENEFIT: Reduces time to commission following industry standards

Testing 70 MPa Hydrogen Fuel Storage Systems

Testing of high-pressure gas components and fuel systems used in alternate-fuel vehicles and fueling infrastructure ensures the safety of the public who purchases and drives these vehicles.

Powertech is a world leader in the testing of high-pressure gas systems, and has been at the forefront of the industry for more than 30 years. In this role, Powertech has continually “pushed the envelope” to test next-generation prototypes. Among its firsts, Powertech was the first lab in the world to test 70 MPa (10,000 psi) hydrogen fuel storage systems. A pressure of 70 MPa offers hydrogen-fueled vehicles a range of up to 500 km (300 miles)—a range comparable to conventional gasoline-powered vehicles. Funded by six major vehicle OEMs, and in collaboration with the world’s leading high pressure component manufacturers, Powertech led a project to develop and test 70 MPa hydrogen fuel storage system components. The project introduced 70 MPa components to the world and allowed the vehicle OEMs to start building their next-generation vehicles, effectively jump-starting the movement toward today’s longer-range hydrogen-fueled cars.

KEY BENEFITS: Ensures safety and advances low carbon transportation capabilities



If hydrogen-fueled vehicles are to meet the demands of today's drivers, they must have an operating range comparable to conventional gasoline-powered cars. This range is achieved by the high-pressure, on-board hydrogen storage in the vehicles.

First 70 MPa Hydrogen Fueling Station

Powertech has been a pioneer in the development of this high-pressure hydrogen technology on both the vehicle and fueling sides. The company designed Canada's first hydrogen fueling station that used 35 MPa pressure in 2001, and subsequently designed and built the world's first hydrogen fueling station capable of delivering hydrogen at 70 MPa in 2002. The 70 MPa pressure provides a range of up to 500 km (300 miles) and makes these alternate-fueled vehicles more practical options. Since 2001, Powertech has designed and constructed 12 turnkey, compressed hydrogen fueling stations which are installed across North America. As an industry leader in hydrogen stations, Powertech is responsible for a number of other firsts. The company pioneered turnkey, containerized hydrogen fueling station packages, which allow for easy installation to respond to the market demand for fueling infrastructure. Powertech also developed the first hydrogen station capable of fueling four fuel-cell vehicles simultaneously, built the first retail-style dispenser, and is currently developing the first 70 MPa fast fill mobile fueler using pre-cooled hydrogen.

KEY BENEFITS: Renewable, environmentally friendly fuel, safety, higher efficiency, carbon reduction



evCloud™ — Electric Vehicle Charging Data

evCloud is a unique web-based platform developed by Powertech to collect and display usage data from over 450 electric vehicle (EV) charging stations across more than 200 locations in British Columbia.

The platform accesses charging data by leveraging the energy metering and communications capabilities built into a variety of types of charging equipment. Among the data collected are: number of charge events, total energy dispensed, approximate fuel displaced, and approximate greenhouse gas (GHG) emissions reduced. Powertech analyzes this data to provide policymakers with insight into current usage patterns, rate of electric vehicle growth, geographic distribution of stations, congestion at stations, and usage at different types of station venues (retail, government, workplace, etc.), while enabling more informed decisions for forecasting and deployment strategies of the electric vehicle infrastructure.

Information is also accessible to the public, allowing the province's growing number of electric vehicle drivers to better understand the location and availability of charging stations.

KEY BENEFITS: Green (clean) transportation solution, greenhouse gas reduction, customer support, and economic impact.

Electric Vehicle Smart Charging

Powertech is an industry leader in developing, testing, and demonstrating electric vehicle (EV) smart charging technologies.

While electric vehicles represent a significant new load for electric utilities, smart charging can help to minimize the impact of charging on electrical infrastructure and capitalize on the potential flexibility of electric vehicle charging loads. Using advanced communication technologies, smart charging solutions include pricing and load management signals that can delay or vary the speed of charging, enabling electric vehicle drivers to avoid charging during periods of high demand or take advantage of available renewable energy. Powertech has developed and tested a variety of smart charging solutions, including smart charging stations (using wifi, cellular and smart metering infrastructure communications), mobile and web apps to help electric vehicle drivers manage their charging, and utility operator interfaces for leveraging electric vehicles and other controllable loads as Virtual Power Plants. In collaboration with BC Hydro and academic researchers, Powertech is demonstrating these innovations in a variety of contexts, including workplace charging, residential charging, and charging depots for fleet vehicles.

KEY BENEFITS: Cost savings for utilities and customers, environmental impact.



Modelling Wood Transmission Pole Risk of Failure

Powertech has developed the first-of-its-kind model for consistently quantifying the remaining life, or risk of failure, of aging wood transmission poles, using structural reliability analysis.

The model is part of a project to support Lines Strategy and Standards of BC Hydro T&D Asset Investment Management, and is designed to help advance the utility's maintenance program for its 120,000 wooden transmission poles in terms of efficiency, prioritization, and saving money. It allows risk quantification of wood pole failure through structural reliability analysis, by incorporating uncertainties such as wood species, weather conditions (wind and ice) at that location, and inspection accuracy. The result of the analysis is a probability of failure for a specified window ranging from one to ten years. The model considers other intervening factors and uncertainties, unlike the current method that uses only pole strength reduction. Powertech's model will permit a consistent replacement policy applied across an entire system with logical justification for replacement. In conjunction with the model, Powertech is also developing a mobile device application for use by field inspectors and a database and web-host server with built-in analytics that will allow administrators to store and manage inspection and asset data and make timely replacement decisions.

KEY BENEFIT: Public Safety, reliability, financial benefit

Use of the model will help to ensure public safety, support system reliability, and reduce expenses by avoiding premature replacement, which can cost \$30,000+ per pole and involve a system outage.



AeroMACS

The global aviation industry needs to upgrade its airport surface communication systems to keep pace with burgeoning demand. Powertech is the only AeroMACS Designated Certification Laboratory in the world with the capabilities to test and certify equipment using the new communications system known as the Aeronautical Mobile Airport Communications System, or AeroMACS.

AeroMACS is a broadband wireless technology for airport surface operations, and has been selected as the next-generation global standard by EUROCONTROL and the U.S. Federal Aviation Administration. The technology operates in the protected aviation spectrum band from 5091 to 5150 MHz for surface operations that involve the safety and regularity of flight. AeroMACS will replace existing cable loop systems, which are expensive to maintain, and will deliver the reliability, security, and speed of broadband wireless connectivity necessary to support new and expanded applications as air traffic systems evolve. Powertech is also actively involved in WiMAX Forum, developing test standards for AeroMACS, and hosted the first AeroMACS Multi-Vendor Interoperability Demonstration Event, which brought together equipment manufacturers from around the world to test their leading-edge equipment.

KEY BENEFITS: Financial benefit, reliability, security



To make cities intelligent, an integrated approach is needed to modernize infrastructure and leverage technology to improve efficiency and capacity. The Intelligent City Accelerator (ICA) program and the living lab at Powertech present a new opportunity to experience and evaluate smart technologies.

Intelligent City Accelerator (ICA)

Cities are beginning to embrace technology to create safer, more comfortable communities for both living and working. By adopting Internet of Things solutions, cities can put technology to work in traffic pattern monitoring, air quality analysis, community safety, and bylaw enforcement in a way never before imaginable. All of this requires mapping the right technologies with an integrated solution that is deployable with low risk and high success. A new collaboration between the City of Surrey, Simon Fraser University, and Powertech Labs is aiming to demonstrate technologies to add intelligence to a typical urban infrastructure. At the heart of this collaboration is Powertech Labs' Intelligent City Accelerator, which provides some of the most advanced and complete facilities for technology integration in North America. The Intelligent City Accelerator uses Powertech's longtime expertise and leadership in networking and communications technologies to host test-bed technology development, rapid prototyping, and demonstration in a simulated real-world environment. The first technology to be tested will be GE's Current Intelligent LED solution, which features software and sensor-enabled LED lighting. Future projects will include optimizing renewable energy and new intelligence for electric vehicle charging and building energy management.

KEY BENEFITS: Community safety, reliability



SF₆ Leak Detector Technology

Powertech is a recognized industry leader in the analysis of sulfur hexafluoride, or SF₆, and its decomposition products.

SF₆ is an anthropogenic gas whose excellent dielectric and arc-quenching properties make it an ideal insulating gas for medium- and high-voltage equipment. However, when the gas decomposes, it forms byproducts that are harmful to equipment, toxic to maintenance personnel—and very difficult to detect at low concentrations. SF₆ decomposition products degrade at a fast rate posing a key challenge for lab analysis. Powertech developed a unique field-portable SF₆ decomposition product detector capable of identifying the predominant byproducts on site at low parts per million levels. The detector can be used on in-service equipment and eliminates sampling errors encountered with traditional instrumentation requiring transporting gas samples to a lab. SF₆ has also been identified as one of the strongest greenhouse gases known. Canada, the United States, and the European Union have regulations governing emissions of SF₆, and utilities are required by some jurisdictions to monitor and report on SF₆ losses. To address this issue, Powertech engineers developed a thermal imaging camera that can produce infrared images of leaking SF₆ gas. With this information, utilities can repair or remediate leaks.

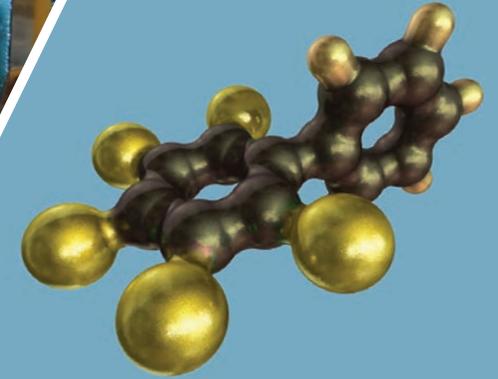
KEY BENEFITS: Safety, fast, accurate detection of low level SF₆ leaks

On-line Transformer Diagnostics

To ensure system reliability, electric utilities must maintain the operation and prolong the life of power transformers. Transformers are not only critical to utility operation, they are also costly to replace and often have multi-year waiting periods for availability.

One key factor affecting the service life of oil-filled transformers is that they are subjected to numerous stresses that degrade their solid paper insulation and can lead to equipment failure. Knowing the condition of the paper is key, because the life of the transformer is determined by the life of the paper. To provide insight into this degradation, Powertech conducted innovative research to identify the chemical compounds that form as the paper degrades and to determine how those chemicals—so-called “paper decomposition markers”—can be detected in the transformer oil. Researchers subsequently developed instrumentation that can be installed on operating transformers for detecting the presence of the markers without taking the transformers out of service. Lab analysis of an oil sample for these chemical compounds can determine the extent of degradation. This information enables utilities to take steps to reduce the paper aging process and extend transformer life.

KEY BENEFITS: Condition based assessment, safety



PCB Online Decontamination

Polychlorinated biphenyls, or PCBs, are chemical compounds that were widely used as insulating fluids in electric equipment until the 1970s, when their use was prohibited due to environmental concerns. However, PCBs remain in many legacy electric components (usually in very low levels as contamination), and managing PCB compounds in power transformers and other electrical equipment remains a constant challenge for utilities. Canadian utilities face an urgency due to federal regulations specifying an end-of-use date of 2025 for equipment contaminated with PCBs. Powertech has patented technologies for destruction of PCBs and developed a new system that is the only one of its kind on the market for the online extraction of PCB compounds from transformer oil. The mobile unit is self-contained and can be directly dispatched to a job site anywhere in the world. It uses extraction cartridges with proprietary absorbent technology to selectively remove PCBs from the oil of an in-service power transformer. The technology reduces PCB levels to less than 2 ppm, and brings the oil back to as-new condition. Decontaminating transformer oil is more cost effective than replacement, and the process allows for reuse of the existing transformer oil, avoiding costly disposal of contaminated transformer carcasses and lowering environmental impact.

KEY BENEFITS: Cost effective, mobile, efficient, safe and convenient solution to PCB management

Pioneering PCB Destruction Technology

In the 1980s, Powertech obtained the first Canadian patent for the destruction of PCBs from contaminated insulating oil and the recovery and re-use of the oil. The process is based on the use of sodium dispersion to remove PCBs at low temperature. Since 1987, BC Hydro has used the process to treat and reclaim over 24 million litres of transformer oil. The process has also been licensed for use in Japan.



Transformer On-line Oil Purification

Powertech has developed unique systems capable of online purification of transformer oil. The systems address a key need of electric utilities—to reduce the level of contaminants in transformer oil in order to maintain performance, prevent failure, and prolong life.

Conventional decontamination methods include on-site hot oil reclamation and retro-filling, which require a power outage, making them costly and time-consuming. In addition, they may not fully remove a contaminant, especially from the solid insulation, and are not selective for specific types of contaminants. The Powertech units are capable of removing decomposition products, moisture, and particulate matter from transformer oil and paper while restoring in-service oil quality to near new. The technology is designed for online, unattended operation and does not require transformer outages. Extraction cartridges, with proprietary absorbent technology, selectively remove contaminants from the oil. Application of these systems helps utilities to maintain optimal transformer operation while significantly reducing the costs associated with contaminant removal, and extending transformer life. Cartridges can be chosen to remove specific contaminants such as moisture, oil degradation products, corrosive sulphur, and recently PCBs.

KEY BENEFITS: Prolonged life of transformer with reduced maintenance cost, safety & reliability, flexible plug and play system

Equipment Health Rating (EHR) of Transformers

Many transformers in North America are approaching the end of their design life and in need of replacement or refurbishment.

To assist engineers in diagnosing and assessing the condition of power transformers, Powertech developed a unique software called Equipment Health Rating, or EHR. The program calculates condition indexes for each transformer component based on test and inspection results, and combines these indexes with equipment information such as age, known problems, and operating and maintenance history to provide a rating of “equipment health”. The Equipment Health Rating software allows experts to review and accept the ratings, provide diagnostics, make recommendations on intervention, estimate the time and cost for corrective actions, and prioritize maintenance. The results can be used to obtain a quick overview of equipment condition and to make comparisons within a substation or across an entire utility.

KEY BENEFITS: Intelligent guide to maintenance and planning managers, improve accuracy in fault prediction



Isolated Safety Ground Device

Powertech, working with BC Hydro, developed a patented isolated safety ground device to protect utility workers from accidental exposure to hazardous voltages during maintenance work on distribution cables.

When maintenance or repair work is required on distribution cables, the core of the cable section is generally grounded at the next manhole to protect the workers from accidental energization. However, this procedure could allow hazardous voltages to occur if a ground fault occurs, for example, at the substation. Powertech and BC Hydro's isolated safety ground device addresses this problem by isolating the cable core from ground at lower voltages to prevent current from flowing through the worker during a ground fault event. If the voltage on the cable core rises above a pre-set safety limit, the device flashes over and provides a low-impedance path to ground. This intervention prevents utility workers from being exposed to dangerous voltages in both ground fault and accidental energization situations.

KEY BENEFIT: Utility worker safety

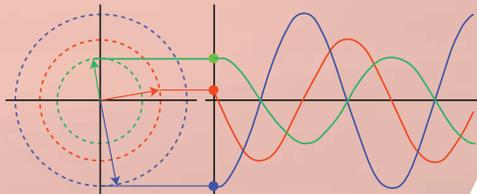
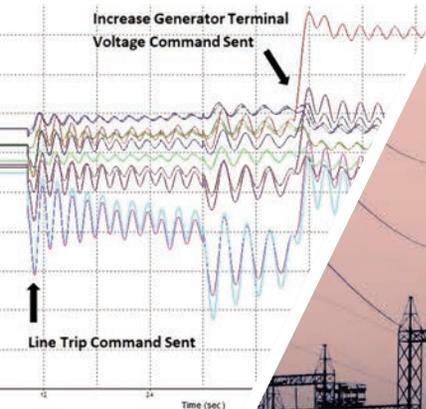
Testing of Self-Lubricating Bearings

Powertech is the only lab in the world with the unique expertise to conduct life testing of self-lubricating bearings for hydroelectric plants operated by the U.S. Army Corps of Engineers.

Wicket gates are used in hydroelectric plants to control the flow of water from the inlet penstocks to the turbine. These gates contain rotating bearings, once made of bronze and requiring periodic lubrication with petroleum grease. Bearing grease had the potential to contaminate the water flowing through plants and to cause environmental hazards, leading the Army Corps to invite manufacturers to develop composite, self-lubricating bearings.

Subsequently, the Corps worked with Powertech to develop a test specification to evaluate the performance of composite bearings and identify the best products. The test specification details an accelerated wear test with low-speed oscillations that simulate worst-case scenarios for wicket gate operations in hydroelectric generating plants. Bearing properties such as static and dynamic coefficients of friction, wear rate, and operating temperature are continuously monitored and reported during testing under wet and dry conditions. Testing helps to ensure that bearings with the longest life and lowest friction are installed in hydro plants and aids in avoiding the environmental impacts of greased bearings.

KEY BENEFIT: Reduces environmental impact, safety and reliability



Emulated Phasor Measurement Unit (ePMU)

Phasor measurement unit (PMU) is a technology for measuring electrical quantities with high resolution and accuracy and with time synchronization across a power system. These measurements provide a real-time view of power system behavior. As new applications have been developed that would use phasor measurement unit data for analysis of grid events, the need arose for simulation of those data in order to test and validate the applications. To meet this need, Powertech developed the Emulated Phasor Measurement Unit module as an add-on function of its Transient Security Assessment Tool (TSAT) software. ePMU is able to provide time-synchronized phasor data from a power system model, similar to those measured by a phasor measurement unit. Unlike other software on the market, Powertech's ePMU is capable of simulating system models of very large sizes, up to 10,000 buses, in real time. In addition, ePMU can serve as a data source for Dispatcher Training Simulators (DTS). The software was the first to provide trainees with real-life-like signals or scenarios in place of simple static data previously used. ePMU is used by utilities and grid operators, including PG&E, ERCOT, and ISO New England.

KEY BENEFIT: Provides simulated phasor measurement unit data for application testing, training and other research

Integrating Intermittent Renewables into the Grid

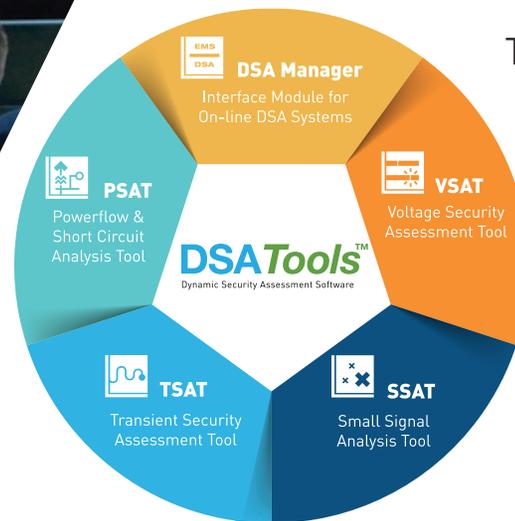
Powertech study engineers conducted ground-breaking research to demonstrate that our dynamic simulation software package, *DSATools™*, can be efficiently used to quantify the effects of integrating intermittent renewables resources such as wind and solar energy into a power grid.

Intermittent renewable energy sources pose a key challenge for power system operation—their output is intermittent and cannot be dispatched reliably to meet demand. Power system planners and operators need to understand the effects of this intermittency on the stability of the power system and to ensure an acceptable performance level. Powertech's *DSATools™* were enhanced to study the effects of intermittent renewable power output under different load conditions and operation scenarios involving a sudden drop in solar and wind power, combined with transmission line outages and wind gusts. The simulations were able to characterize the interaction of Automatic Generation Controllers, operation of a peaking unit, and battery energy storage. The platform that Powertech developed demonstrates the feasibility and real value for electric utilities of studying the impacts of intermittent resources using *DSATools™* and thereby supporting their future reliable and secure integration.

KEY BENEFITS: Reliable use of intermittent renewables, and grid security



Technology. Innovation.



On-line Dynamic Security Assessment (DSA)

Powertech pioneered the technologies for on-line dynamic security assessment (DSA).

Maintaining grid security and the reliable supply of electricity is a fundamental requirement for power systems operations. Traditionally, the stability and transfer capability of power systems are analyzed off-line, and this process involves using estimated system conditions with conservative assumptions, resulting in the assessment of limited operational scenarios and reduced transfer capability of the grid. With on-line DSA, the analysis software is integrated directly to a power system's energy management system and assesses the system security in continuous cycles. Using real-time captured system conditions, the on-line DSA provides important information such as system security limits, types of criteria violations, critical contingencies, and remedial actions needed to prevent system failures. Powertech's on-line DSA technology has been a market leader for more than a decade, and is used by seven of the nine independent system operators (ISOs) in North America and by utilities around the world. The Electric Reliability Council of Texas Inc. (ERCOT), which serves as the ISO for most of the state of Texas, estimated that by using on-line DSA an annual saving of US\$27 million could be achieved without compromising the reliability of its grid operation.

KEY BENEFITS: Real time security, reliability of power systems, reduce risks of blackouts, cost effective performance enhancement

Small Signal Analysis Tool (SSAT)

Powertech developed the state-of-the-art software tool, called Small Signal Analysis Tool (SSAT), for analyzing power system low-frequency oscillations—a complicated power system phenomenon with the potential to cause widespread blackouts.

On August 10, 1996, the western electric grid in the area of the Western Electricity Coordinating Council (WECC) experienced a massive blackout, breaking the area into four islands. The power outage lasted up to six hours in some areas, affecting 7.5 million customers in parts of Canada, Western U.S., and Mexico. The failure was associated with unstable low-frequency oscillations due to insufficient damping for a critical oscillatory mode in the system. Subsequently, seven major North American utilities, including BC Hydro, funded the development of the SSAT tool, which provides comprehensive capabilities for small signal analysis of large power systems. SSAT uses advanced computational algorithms and supports a wide variety of models for analyzing small signal stability. Recently SSAT was used to conduct a small-signal stability analysis of a large interconnected power system. This provided valuable recommendations for tuning the existing and adding new power system stabilizers in the system to accomplish optimal performance. Today SSAT is being used by many grid operators, power utilities, universities, and research institutes around the world.

KEY BENEFIT: Increases reliability



Powertech

12388 - 88th Avenue
Surrey, British Columbia
Canada V3W 7R7

604.590.7500
info@powertechlabs.com
powertechlabs.com