



Specialist Consultants
to the Electricity Industry

PSC NEWS

Helping our clients power the world



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PSC - 20 Years of Electricity Market Systems

Electricity is an ephemeral thing – it is difficult to store and must be available instantaneously on demand. So it is not something that suppliers can just keep in a warehouse, ready to deliver when needed. The engineering solution was to have central controlling authorities to coordinate the dispatch of generation to meet demand in real time and to predict and arrange to cover future demand.

However this centralised engineering approach was in conflict with the zeitgeist of the 1990s for privatisation and market forces, and with the availability of powerful computers to run optimisation software it became possible to have market-driven electricity generation dispatch, whereby the market decided which generation units to dispatch and what price to pay.

New Zealand was the ground-breaking earliest adopter of a Wholesale Electricity Market, and PSC have been there right from the beginning. That pioneering Transpower development was the catalyst for PSC to embrace wholesale market systems, and soon we found ourselves helping ISOs (Independent System Operators) to meet their project requirements in jurisdictions around the world.

Transpower New Zealand - the Frontier

In June 1995 the NZ Government announced significant reform of the NZ electricity industry including a market for buying and selling electricity through a wholesale pool. EMCO had been set up in 1994 as a consortium of market players to agree the market rules, and Transpower, the independent grid operator, was tasked with dispatching the market to rules agreed by the market players.

ESCA of Bellevue, USA was then the foremost developer of advanced solutions for the wholesale electricity industry. ESCA, PSC, Synergy and Transpower worked in dialogue with EMCO to agree and test a set of market rules for a Locational Marginal Pricing solution that were feasible to implement with the technology and time available. As this meant a major change in Transpower's business processes and control centre culture, Project "Enterprise" with PSC in a leading role worked to take Transpower "where no man has gone before".

In June 1996 a publicly committed start date of 1 October was sprung on the team. ESCA, with embedded key resources from PSC, worked feverishly to deliver SPD (Scheduling, Pricing and Dispatch), while Project Enterprise engaged warp drive. Against all odds, the new market system went live on schedule, 1 October 1996!

Of course there are a lot of learnings from using a pioneering system, and so there was an ongoing process of refinement of both the market rules and the tools needed to implement

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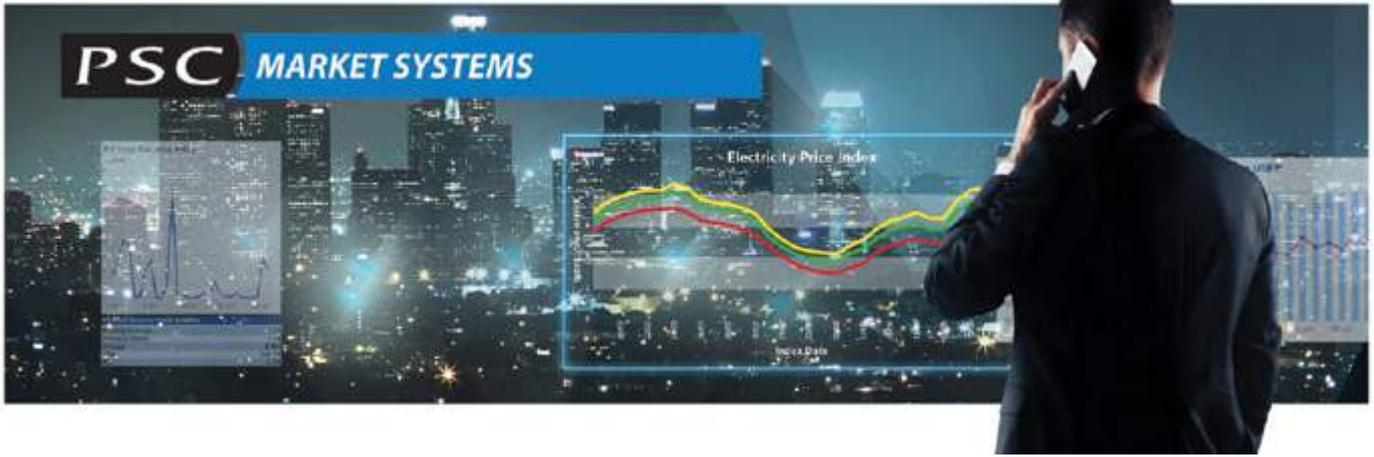
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them, in which PSC played an important part. For example market dispatch was initially on a half-hourly basis, but later was tightened to a 5-minute Real-Time Dispatch (RTD), and later again 5-minute Real-time Pricing (RTP) was implemented (2002) to give demand customers the ability to respond to fluctuations in the wholesale spot prices on a 5-minute basis (previously these customers had only half-hour pricing information available the next day).

PSC was responsible for development and support of a number of additional facilities to the core market system to extend and fill gaps in the original design, such as Reserves Management Tool (RMT) (2000), and later in 2003/4 a matching study tool to allow support personnel to carry out dynamic studies of the reserves model.

PSC designed and developed a buffering facility for RTD, plus a backup Stand-Alone Dispatch mode in 2003 to improve availability by allowing 5 minute dispatch to continue despite an outage in the main market engine or database. This work completed by PSC provided a major step in market system availability.

The original design of Transpower's market system assumed that changes to the electricity network model of branches and buses would be relatively rare, but this was not in fact the case and managing the changes with dummy branches and a burgeoning number of constraints was becoming difficult. PSC investigated, designed and managed a complex project to make extensive changes to the market system to allow branches and buses to change in the time dimension, which went live in 2004.

EMC Singapore

Energy Market Company Pte Ltd (EMC) operates Singapore's wholesale electricity market. The National Electricity Market of Singapore (NEMS) opened for trading on 1 January 2003. PSC has been there right from the beginning, having been engaged in December 2002 to provide specialist technical support for the market clearing engine (MCE).

EMC's market system is unique, being a bespoke Locational Marginal Pricing system developed by PA Consulting group. EMC disengaged from the suppliers prior to market commencement, so PSC with our market system expertise was brought in with urgency to solve final issues prior to go live. PSC has been instrumental in assisting EMC with functional improvements and extensions to the MCE over the years.

A significant enhancement was migration of the PA-supplied VB6 technology to run under the .NET framework with a new object model.

This not only provided EMC with improved efficiency and reliability, it also facilitated the development of the off-line analysis and training tools (EMSTAT). EMSTAT was designed and developed by PSC to allow convenient analysis of market incidents and scenarios, also training and documentation. EMSTAT was developed in 2 stages, with proof of concept stage completed in 2005 and the full tool completed in 2006. PSC continues to provide MCE support and enhancement services to this day, a successful 14-year record of service.

Transpower Second Generation System

In 2006 Transpower New Zealand let a contract for a complete replacement wholesale market system to Areva (previously ESCA), with PSC as a partner to Areva to deliver documentation and some software components. In particular PSC developed a Stand-Alone Dispatch (SAD) system which runs independently of the main system to provide seamless continuation of the 5-minute dispatch of the market in cases of major failures of the main system. SAD has been instrumental in achieving 100% availability of market dispatch. Once again some PSC staff were embedded in Areva's development team. Other key components provided by PSC in NZ included the integration of the Reserves Management Tool (RMT) solver into the new system, the Electronic Dispatch Facility (EDF) and integrating an upgraded Outage Management system in Transpower's EMS.

When Transpower later took over direct management of the project, PSC staff were integrated into Transpower's project team in project management, testing and technical advice roles, with a total of 18 PSC staff involved over this major project. Following commissioning to service in 2009, PSC staff remained to provide specialist support expertise and continue in this role with Transpower to this day, a proud 20 year record of market support to Transpower.

Western Australia

The Wholesale Electricity Market (WEM) for the South West interconnected system of Western Australia (SWIS) commenced operation on 21 September 2006. This involved the disaggregation of Western Australia's vertically-integrated electricity utility and setting up the Independent Market Operator (IMO). ABB implemented the market systems required to operate the new market.

In 2008 PSC took over market systems support, with a short transition period to train six PSC support staff in a system that was quite

different from the nodal pricing systems of New Zealand and Singapore. PSC was selected due to our technical expertise in the analysis of market rule changes, development testing and support of the system for market rule changes, as well as major projects experience.

Major projects PSC worked on included:

- Market Evolution Project (MEP) 2012 – introduction of both Balancing and Load Following Ancillary Services (LFAS) markets. PSC were heavily involved in the market design, implementation and integration of the project.
- Gas Bulletin Board (GGB) project 2013 – a customised designed web application that receives gas production, transmission and consumption information from gas market participants and presents that data in a meaningful way to the public.
- Settlements Processing Account Reporting and Transaction Administration (SPARTA) 2014 – an accounting reconciliation and invoicing application for final settlement of the market.

In 2015 the market operator functions were transferred to the Australian Energy Market Operator (AEMO). PSC have continued to provide market systems support for the new market operator. PSC had already for many years provided market systems expertise to the AEMO, particularly in its former incarnation as NEMMCO. PSC continues to be a reliable service partner with our specialist expertise.

North America

In 1996, FERC issued the landmark ruling 888 - Open Transmission Access, which enabled competitive electricity markets to become a reality in North America. PSC's experience was sought after and for the next decade during the big build-up of markets in North America, PSC assisted first ISO-NE, then PJM, ERCOT, Cal ISO, SPP, and MISO evolve market design and meet the expectations of clients and regulators.

Although PSC did not directly market the technology, technology companies like ESCA (now GE Grid) benefited from PSC's expertise in design, coding, implementation, testing and support. PSC has assisted in the evolution of the North American markets from real time energy market based on LMP, to today's most common designs including co-optimized day ahead and real time markets, Transmission Rights, Capacity Markets, and Market Settlements.

In many ways PSC's NZ roots assisted in global market development. New Zealand with its forward thinking and ability to implement policy and systems served as a global test bed for markets where others could observe and learn. Many of today's challenges in North America have been addressed in NZ, and our North America centre of excellence in Kirkland, Washington, taps into our global pool of knowledge to provide innovative solutions to benefit our clients.

The World

The PSC markets team is truly a global team with close coordination between the market systems experts in New Zealand, Australia, Singapore, North America and Europe.

20 years after trekking the first wild frontier, PSC finds itself once again on a new frontier of electricity markets - distributed energy and distribution level markets. Similar to the early days of wholesale

markets, PSC is on the forefront of market design and technology for these emerging distribution or "micro markets". Using state of the art solvers and Microsoft cloud technology and services, PSC is bringing a new realm of capabilities to our clients.

MARKET TIMELINE

Pre-95	The old way – Centralised planning, scheduling and dispatch
1995	NZ Government announces market reform of NZ Electricity Industry
1996	PSC helps ensure that the pioneering NZ Wholesale Electricity Market goes live on schedule on 1st October. In USA, FERC issues ruling 888
1999	ISO-NE implements wholesale energy market
2003	Singapore market goes live with PSC support USA markets move toward Standard Market Design
2005	MISO energy market launched
2005 - 2006	EMC Singapore - implement EMSTAT tools Western Australia SWIS market commences 2006
2008	PSC takes over WA- IMO market support
2006 - 2009	Transpower generation 2 market system development and implementation (MSP)
2010	ERCOT nodal market goes live
2011	PJM's Advanced Control Centre (AC2) goes live
2012	WA Market Evolution project
2013	WA Gas Bulletin Board project
2014	WA Settlements Processing (SPARTA) project
2016	20 Years of PSC serving electricity market clients



Generator Testing, Modelling and Compliance with Genassure

In 2014 Genassure International became a member of the PSC Group. Genassure and PSC have been working together to provide our clients with generator testing, modelling and compliance services for their generation assets.

The Genassure test system is an automated solution for the testing and assessment of generator performance. Many grid operators have statutory requirements for the performance of connected generation assets. The Genassure system independently verifies compliance through a series of automated tests. Advantages of this system include automated testing to improve the testing process and reduce asset downtime, precision data acquisition and processing techniques ensures more accuracy in the final analysis and reporting, independent compliance verification, standards compliant and built in internal safety mechanisms.

The team at Genassure provides the skills and resources to develop and enhance testing solutions and to perform the on-site testing service. PSC provides the analytical expertise to develop and validate the models required by grid operators and regulators. The combination of these services puts Genassure and PSC at the leading edge of service offerings in this area.

Services in Generator testing and modelling include:

Generator Compliance Management

- Strategic planning
- Independent technical review and advice

Excitation Testing (AVR) including

- Step response tests
- Closed loop frequency response tests
- Open circuit magnetisation curve tests
- Power system stabiliser (PSS) testing
- Over and under excitation limiter testing

Governor Testing including

- Step response tests
- Stability tests



- Frequency control ancillary service tests
- Deadband testing

Modelling

- Select simulation models or develop custom models to represent the excitation, or governor system topology
- Overlay test results with simulation results
- Tune simulation to match tested response
- Source code for custom models

Genassure and PSC are able to offer a complete solution including strategic planning, testing, modelling and validation for our clients. For more information, please contact Peter Brown, Genassure Manager at peterb@genassure.com

Please also visit www.genassure.com

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ATCO Canada EMS Strategy Roadmap

Utility owners all recognize the importance of maintaining a strategic plan for their EMS and DMS systems, but are often so busy with managing the reliable operation of their current system that they don't have the time or resources to perform a careful assessment of their current and future needs. PSC solves this problem by working with key stakeholders to capture an all-encompassing view of the utility perspective, before applying our neutral and holistic understanding of EMS system operations derived from supporting numerous utilities around the world.

ATCO Canada knew their own transmission system well – but they wanted to get the whole picture. Because they were familiar with PSC's expertise in EMS assessment and strategic planning for other utilities

in Canada and around the world, including AltaLink in Calgary, ATCO selected PSC to perform a review of ATCO's transmission system tools and capabilities in order to assess how well the tools were meeting business goals and regulatory and security mandates.

PSC interviewed key stakeholders and compared the ATCO system with peers in the industry and with alternative EMS vendor capabilities to identify current needs and requirements of the EMS and determine whether they were being met by the current systems and tools. The product of this assessment was a 5-year strategy roadmap for the EMS that provided ATCO with the framework they needed to position their EMS for the future.

CIGRE Canada 2016

The threat of electricity network disturbance is becoming greater every day, due to the increasing severity and frequency of inclement weather, as well as physical and cyber-attacks.

The International Council on Large Electric Systems (CIGRE), whose primary purpose is to promote collaboration between electric power system experts from around the world, recognizes this threat and sought to generate thought leadership around the topic of network resiliency.

As a thought leader in the industry, PSC North America's Director of Power Networks, Marc Brunet-Watson, participated in a panel discussion on what resiliency means for networks, and led a discussion on making the business case for resiliency-based investments.

"Reliability and resiliency are not the same thing," explains Marc. "Reliability is a measure of service, like: 'what is the impact on the grid and how can we restore service?' That's been the regulatory model to date. Whereas resiliency says 'Ok, there's been an impact on the grid, service is down – what are the consequences that result from that, what are the impacts *beyond* the grid?'"

"Consumers understand the benefits of network resiliency, and they want them," says Marc. "Our present regulatory model relies on reliability-based investment, and service providers are grappling with how to fund these new resiliency-based investments."

Marc and his team routinely work with organizations in North America to assess how they can better manage system shocks.

PSC has been the Diamond Sponsor of the annual CIGRE Canada Conference for four years running.



From left: Roul Martin, Sr. Planning Engineer; Marc Brunet-Watson, Director of Power Networks; Tony Armstrong, PSC CEO and Co-Founder; Anupama Konara, System Studies Engineer; Alex Boyd, CEO North America; Ken Pratt, Director of Operational Technologies

Seoul International Conference on the Electricity Market (SICEM)

Big changes are coming for energy consumers, as revolutions in consumer-to-consumer financial transactions presented by technologies like blockchain are providing the framework for what many in the energy industry believe to be the first viable platform for energy consumers to buy and sell energy direct from each other across a microgrid.

PSC's Randy Berry spoke to the challenges and opportunities facing electricity markets as a result of the proliferation of consumer energy storage solutions and micro markets, while at the Seoul International Conference on the Electricity Market – an annual meeting hosted by KPX, the Korean Power Exchange.

The theme of this year's conference, held in Seoul on September 27, was "Advancing Electricity Market through Vitalization of Energy-Related New Industries."

PSC works with utilities and energy clients around the world to support emerging Distributed Energy Resource (DER) projects including battery storage, wind and solar generation.



PSC Vice President of Business Development Randy Berry holds up a cell phone whilst discussing the powerful role of the consumer in modern energy markets



Successful Aerial Laser Survey (ALS) in New Zealand

PSC in partnership with Opten, the leading ALS service provider, has been successful in completing an aerial laser survey for Transpower New Zealand. This follows on from PSC's ongoing 12 year involvement in aerial laser survey technology and data services delivered for a range of clients.

Aerial laser surveying of transmission lines is conducted by a helicopter fitted with a high accuracy laser scanning system. The laser scans a swath under the helicopter's flight path, detecting conductors, towers, the ground plane, and other features such as roads, buildings and vegetation. Photo systems are used to supply imagery for object identification and as an accurate record at date of survey. GPS receivers are placed strategically along the route to provide differential GPS for accurate helicopter positioning. Weather stations are also placed in the field to enable accurate modeling through calculating the conductor temperature at time of survey. All this data enables the creation of accurate PLS-CADD models of the surveyed transmission lines to assist owners to manage their assets.

Transpower New Zealand 2015/16 survey

The first survey stage for Transpower was completed in 2015. The latest generation Optech Orion scanner was used as it enables high quality pickup of small wires.



1400 km of transmission line survey was completed, along with a variety of small area topographical surveys. A combined GPS and GLONASS positioning approach was used to provide maximum positioning accuracy and availability. Along with the LiDAR and positioning systems, two photo systems were onboard to supply high quality imagery, and ground weather stations placed by New Zealand's National Institute of Water and Atmospheric Research (NIWA) provided the weather data input for the metrological modelling used for conductor temperature calculations.

PSC and Opten have now successfully

completed stage two of the project in 2016 with the supply of detailed data processing to produce the final PLS-CADD models required by Transpower, along with orthorectified photos and other imagery.

PSC's Transmission Line Services

Along with its aerial laser surveying services, PSC is able to offer a full range of transmission line engineering services using the latest line modelling and engineering tools.

PSC opens New Kirkland Office

PSC North America is expanding so fast that we've outgrown our old home. We are pleased to announce that we have opened a new North American headquarter office in Kirkland, Washington. The office provides a full-time home for management and administrative staff, as well as numerous workspaces for traveling or temporarily located PSC engineers.

Thank you to everyone who helped us get settled during the Open House on September 29th.

PSC North America's new physical address is:

Power Systems Consultants, Inc.
4010 Lake Washington Blvd NE, Suite 300
Kirkland, WA 98033, USA



APEX 2016

The Association of Power Exchanges (APEX) was formed to facilitate development and communication of ideas and practices in the operation of global competitive electricity markets. Participants come from Asia, Australasia, Europe, North America and South America.

PSC has been active in APEX for many years in sponsoring the annual APEX conference. This year PSC was a sponsor of the 2016 APEX Conference, hosted by XM in Medellin, Colombia. This was the 21st annual meeting of the association.

Integration of Distributed Energy Resources and renewables was a major point of discussion at this year's event, with many panelists addressing the question of how to handle the penetration of distributed energy generation coming from both sides of the meter.

PSC's Randy Berry was a speaker on the APEX panel devoted to Advanced Technology, Information, and Innovation. Randy spoke to the opportunities presented to electricity markets by advanced technologies leveraging open source software and cloud computing.

"Our clients all have a cloud strategy now," says Randy. "For many it is taking back-office functions to the cloud and for some it is moving analytical functions to the cloud."

Simon Oliver, Senior Market Systems Engineer at PSC, was also in attendance. Simon noted the increased attention to market integration around the world:

"Another topic addressed was the global trend toward larger balancing regions, as certain networks and markets around the world expand and become more integrated. Proponents of market integration cite the benefits of increased connectivity, such as reserve sharing and economy of scale."

PSC provides consulting services to electricity market operators throughout the world. PSC's services include market systems design,



PSC's Simon Oliver and Randy Berry pose with a local artist who designed the APEX floral arrangement shown here.

implementation, integration and support. For 20 years, PSC has assisted in the successful implementation, operations and support of market systems. In addition to using PSC's market system consulting services, Independent System Operators (ISOs) and Regional Transmission Operators (RTOs) also utilize PSC's Operations Technology, DER, Power Networks, and HVDC range of consulting services fully aligned with the needs of our clients.

New PSC office in Melbourne



After 9 years and with the looming re-development of our recently vacated office in Melbourne into a retail store, PSC Australia was tasked with locating a new work space that was closer to PSC's Melbourne client's offices.

In late October, PSC moved into a new office at Level 9 - 440 Collins Street in Melbourne. The new office can accommodate all permanent or visiting PSC staff and has a large conference room suitable for hosting training courses, as well as smaller meeting rooms.

For more information, please contact PSC Australia's GM Operational Technologies & Market Systems Andrew Dunn at: andrew.dunn@pscconsulting.com



PSC WELCOMES NEW STAFF

RAMESH HARIHARAN

PSC is pleased to welcome Ramesh Hariharan, a power systems engineer with more than 10 years of experience in the electrical power industry. Ramesh holds a Master of Science degree in Electrical Engineering from the University of Texas in Arlington. After receiving his degree, Ramesh joined Pacific Corp as a Transmission Planner, where he played an integral role in the development and submission of base cases to WECC (Western Electricity Coordinating Council). Prior to joining PSC, Ramesh ran the FACTS study team for SVC (Static VAR Compensator) design at GE/Alstom in Philadelphia. Ramesh has performed System Impact Studies for large generator interconnection and transmission service requests. Ramesh has experience using PSCAD, RSCAD/RTDS as well as PSS/E, and will be an integral part of the growing system studies business in North America.



ROUL MARTIN

PSC North America is pleased to welcome Roul Martin to the Power Networks team in Vancouver, B.C. Roul grew up in Jamaica, where he completed his BSc and MSc in Electrical Engineering with the University of the West Indies, Trinidad and Tobago. Roul began his career working in SCADA/EMS – particularly advanced applications like Dispatcher Training Simulator, for the Jamaica Public Service Company (JPS). In 2009, Roul moved to Canada and began working with the Alberta Electric System Operator, where he worked until joining PSC. Roul has more than 18 years of experience in transmission system real-time monitoring, planning and operations.



PSC Scholarship - 2016

PSC has for over 10 years provided support to the University of Canterbury, School of Engineering. The establishment of the PSC Scholarship in 2005 enhances the relationship between PSC and the Electric Power Engineering Centre (EPECentre). The EPECentre is based in the Department of Electrical and Computer Engineering to promote and support the education of power engineers and the study of power engineering as a field of excellence in New Zealand.

The PSC Scholarship is open to students in their 3rd professional year, who are focusing on power engineering subjects and have demonstrated excellence in their studies.

Congratulations goes to 2016 PSC Scholarship recipient Jesse Stuart. Jesse was selected from a strong field of submissions and in addition to his outstanding academic achievements, has gained valuable industry experience with Mighty River Power and Trustpower. He is currently the CIGRE NGN (Next Generation Network) events coordinator, helping to introduce young engineers to the power engineering industry.



PSC Scholarship recipient Jesse Stuart (R) with PSC's Director of Engineering Ranil de Silva

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