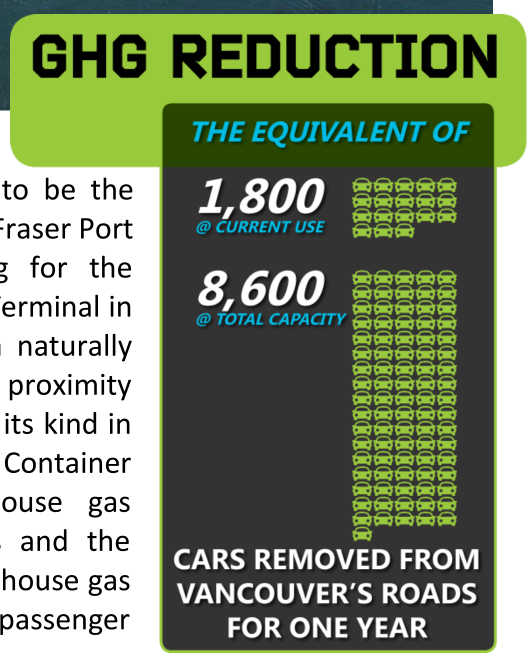
PROJECT BACKGROUND

The Vancouver Fraser Port Authority is responsible for the largest and busiest port in Canada, the Port of Vancouver. Their mandate, as outlined under the Canada Marine Act, is to contribute to the competitiveness, growth, and prosperity of the Canadian economy, while providing a high level of safety, protecting the environment, and responding to local needs and priorities.

Aerial photo of Centerm Container Terminal in Vancouver



In support of this vision and in alignment with their vision to be the world's most sustainable port, on July 22, 2015, the Vancouver Fraser Port Authority and the federal government announced funding for the installation of shore power facilities at the Centerm Container Terminal in Vancouver. The Centerm Container Terminal is located in a naturally beautiful setting on the South Shore of the Burrard Inlet in close proximity to Vancouver's downtown core. As the first green initiative of its kind in Canada that adheres to international standards, the Centerm Container Vessel Shore Power System significantly reduces greenhouse gas emissions and improves air quality for terminal employees and the surrounding community. It is projected to reduce annual greenhouse gas emissions by 7,125 tonnes – the equivalent of removing 1,800 passenger vehicles from Vancouver's roads at current capacity.

Container vessels have a continuous power demand and run their diesel-burning engines non-stop while at berth to provide power to essential vessel loads such as motors, heating, ventilation, navigation systems, emergency systems, and refrigerated containers housing perishable goods. A container vessel moored at a terminal may have a power demand of up to 7.5 Megawatts, and the vessel diesel generator engines used to power their loads contribute to local air and noise pollution.

Shore power, also known as cold-ironing or alternative marine power, can be used by container vessels at berth to plug into the local electrical grid so that they can turn off their diesel generator engines, eliminating emissions and reducing operating costs.

Joint project funding for the Centerm Shore Power System was provided by Transport Canada's Shore Power Technology for Ports Program and the Vancouver Fraser Port Authority. PBX Engineering led the design effort and acted as the owner's representative throughout the construction process. The project team and primary project stakeholders included:

- *Project Owner:* Vancouver Fraser Port Authority
- *Project Funding:* Vancouver Fraser Port Authority & Transport Canada
- *Terminal Operator:* DP World Vancouver
- *Lead Design Firm:* PBX Engineering Ltd.
- *Structural & Civil Design:* CWA Engineers Inc.

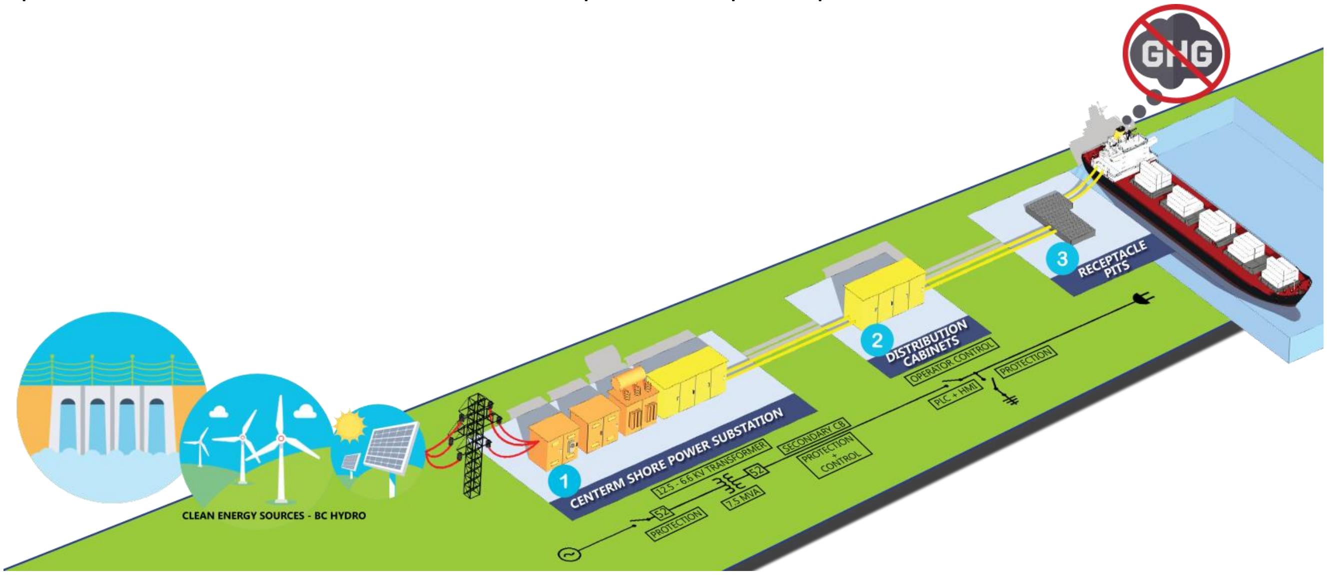
PORT of vancouver   Transport Canada   DP WORLD Vancouver

PBX ENGINEERING   CWA ENGINEERS INC.

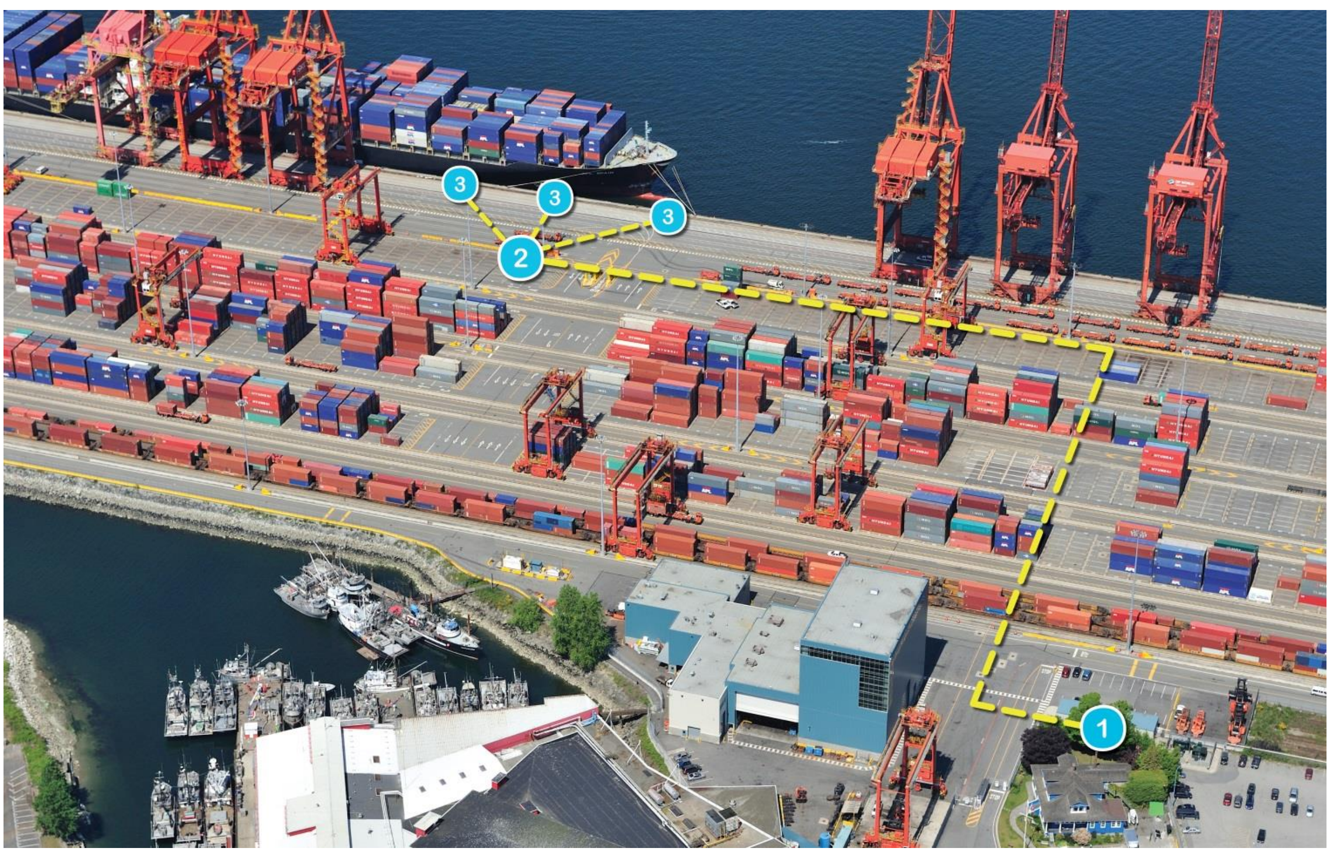
SOLUTION

The Centerm Berth 5 Shore Power System consists of an onshore high voltage power distribution system which allows vessels to connect to the electrical grid and shut-off their diesel generators for the duration of the vessel at-berth period. The shore power system was designed and built in compliance with international IEC/ISO/IEEE 80005 Cold Ironing Standards, BC Hydro Standards, CEC 2015, and other applicable codes, statutes, standards, regulations, and by-laws.

In order to preserve room at the congested berth area, the shore power system was designed with a unique distributed architecture. A unit substation was installed on the south side of the terminal where there was adequate space to accommodate its installation, and the smaller berth face distribution equipment was installed inside the terminal in close proximity to Berth 5 where an operator has a clear view to the three shore power receptacle pits installed at the berth face.



Shore Power System Diagram

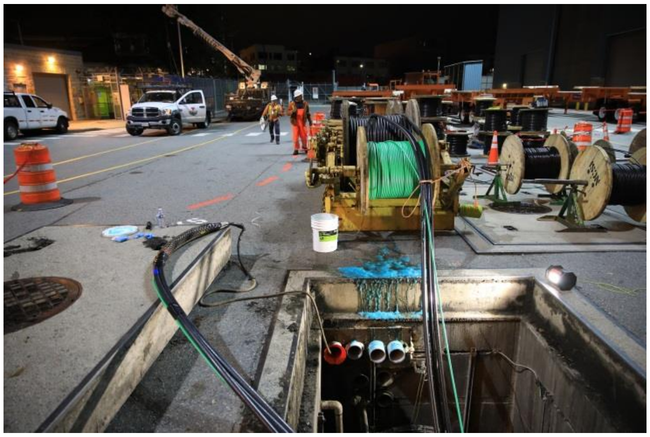


Overhead Map of Centerm Container Terminal Depicting Device Locations and Cable Routing

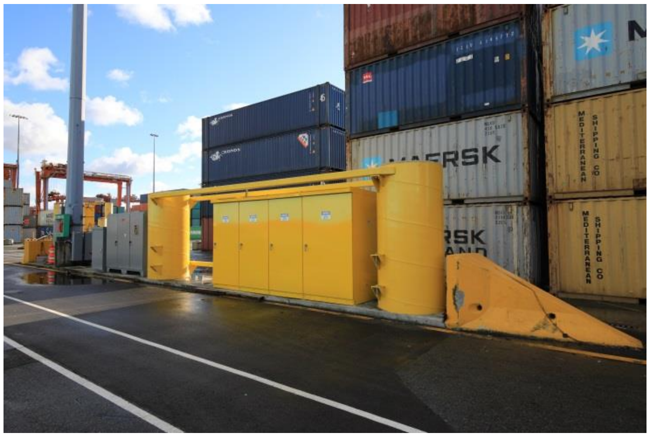
Service power is provided at 12.5kV by BC Hydro. The unit substation steps down the 12.5kV service voltage to 6.6kV, which is the standard shore power voltage for connection to vessels. The shore power system capacity is 7.5 Megawatts, as dictated by the international shore power standard. The unit substation includes the primary distribution and protection equipment, BC Hydro and port power metering, 7.5MVA transformer, protection relays, and PLC and SCADA control systems.

7.5 MW Unit Substation

From the unit substation, power is fed to the berth face distribution equipment via high voltage feeder cables that were installed through a combination of new and existing electrical duct banks. The berth face distribution equipment provides 6.6kV shore power to vessels moored at Centerm Berth 5 through three receptacle pits installed along the berth face. One vessel can be connected to the shore power system at any time. The berth face distribution equipment is comprised of the receptacle pit feeder load break and ground isolation switches, system protection relays, fibre optic communications, and PLC and SCADA control systems including a local operator control interface. Any container vessel compliant with the international IEC/ISO/IEEE 80005-1 standard can be connected to the shore power system through the 6.6kV receptacles located inside each receptacle pit.

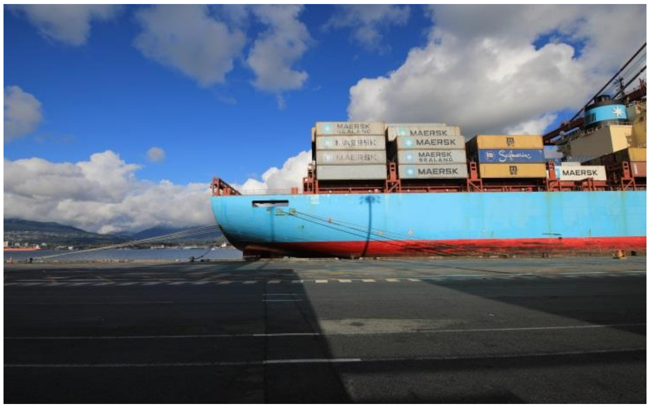


6.6 KV Cable Installation Across Terminal

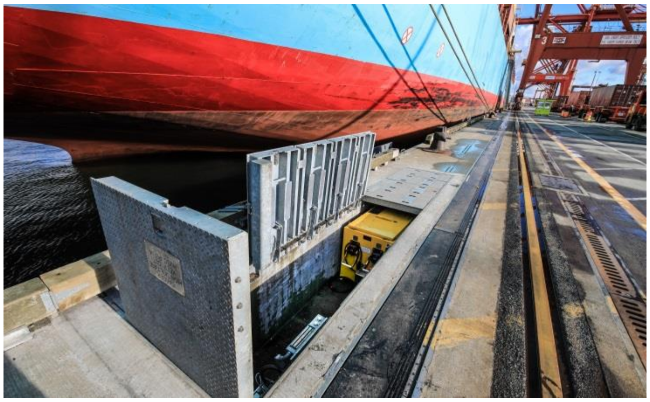


6.6 KV Berth Face Distribution Equipment & System Control

Protection & Control Equipment



Underground 6.6 KV Duct Bank to Berth Face

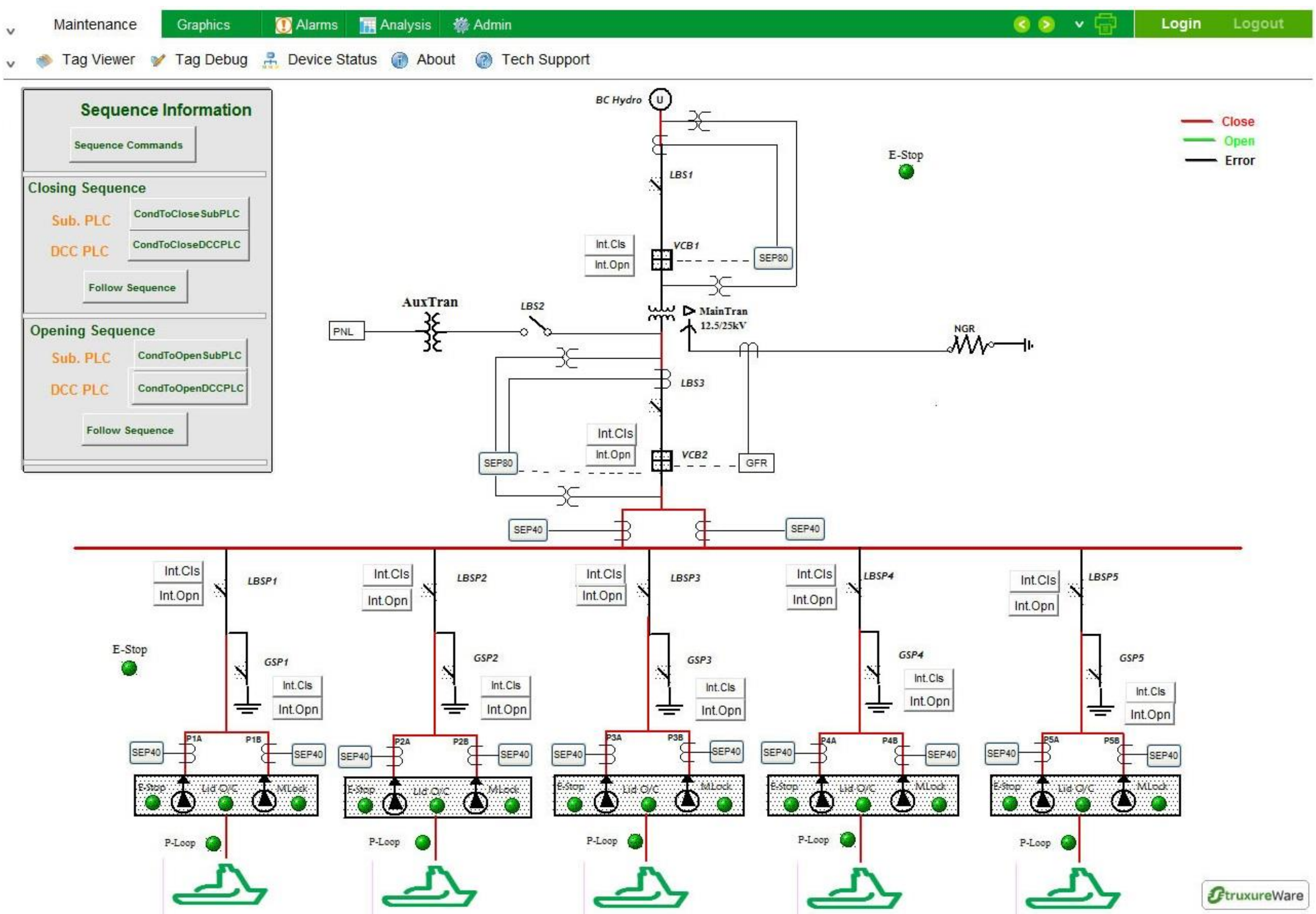


Berth Face Receptacle Pit

The vessel–shore power system is designed to be safe and easy to operate. It can automatically isolate itself in the case of unsafe conditions, locate and isolate electrical faults, and safely disconnect the vessel in case of load overcurrent, short circuits, faults on the BC Hydro service feeder side, over or under voltage or frequency, or reverse power.

PBX assisted the Port in preparing safe connection working procedures, taking into consideration site conditions and labour requirements. The process for connecting a vessel is outlined below:

1. Vessel arrives at Centerm Berth 5.
2. Shore power cables are extended from the vessel to the receptacle pit, and communications and 6.6kV plugs are connected to the receptacles.
3. Receptacle pit lids are closed and the area is cleared of all personnel.
4. Shore system operator energizes the feeder cables between the vessel and the shore system from the berth face distribution equipment.
5. Vessel generators are synchronized with the shore power grid and connected through an automatic synchronization controller located onboard the vessel.
6. Vessel automatically offloads and disconnects the generators from the vessel distribution system. The maximum duration of the closed transition transfer is limited to 90 seconds.
7. Vessel generator engines are stopped, and the vessel electrical loads are now powered from the shore-side electrical power grid.



Operator Control Interface

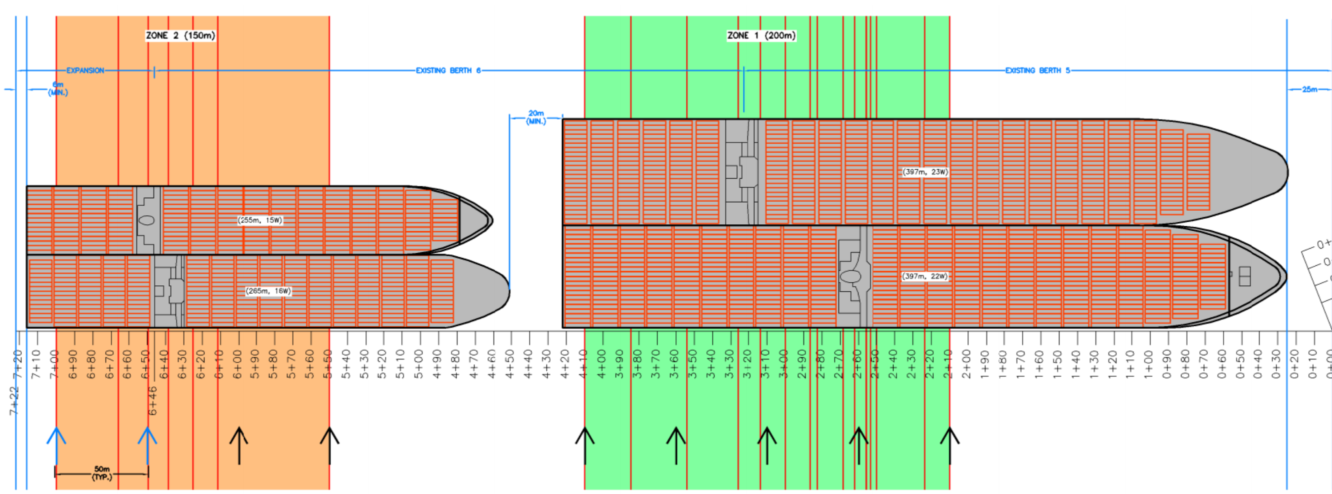
Throughout the design and construction process there were a number of unique design approaches and outstanding engineering achievements; these are summarized below.

Berthing Study

In order for a vessel to connect to a shore power system, it must extend cables from its onboard Alternate Marine Power (AMP) equipment down to a receptacle pit located on the berth. Due to the limited length of the cables, the AMP equipment on the vessel is required to be aligned within 20 meters of a receptacle pit location. Factors such as berthing configurations, vessel sizes, and the location of the on-vessel AMP equipment dictate whether a vessel will be able to connect to a given receptacle.

This issue is usually addressed by installing receptacle pits at regular intervals along the berth face (typically every 60 meters). This solution works well in green-field installations where receptacle pits can simply be cast into the new berth face, however, when installing receptacle pits at an existing terminal this approach is very costly.

Project budgets dictate the number of shore power receptacle pits that can be installed. In order to maximize the ability for ships to connect to the shore power system, PBX used an innovative approach and developed a process for conducting a detailed berthing study to optimize the receptacle pit locations and increase the chances of a vessel being able to connect. An analysis of the container lines serving the Pacific North West region was conducted. An outreach survey to the various container lines was performed to determine their vessel sizes, the location of onboard AMP equipment, and their plans for future new build vessels. A comprehensive analysis and summary study was prepared to optimize the receptacle pit locations, taking into account vessel length, number of vessels berthed simultaneously, location of AMP equipment, berth configuration and berthing orientations, length of connection cables, and tidal fluctuations and vessel buoyancy during on- and off-loading.



Berthing Study Vessel Modelling

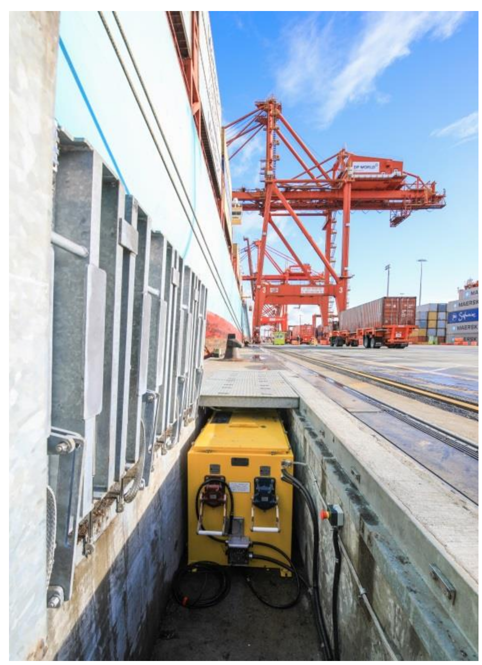
Technical Committee

The Centerm Shore Power System was designed to the IEC/ISO/IEEE 80005-1 International Standard for High Voltage Shore Connection (HVSC) Systems. The working group that developed and administers the standard meets annually to discuss, review, and accept proposed changes. Representatives from PBX attended their 2016 annual meeting which was held in Vancouver BC. This was a unique and interactive opportunity for the PBX engineers to gather more information regarding the best practices from industry experts, as well as to provide valuable input to the working group about our experience preparing a design to the standard that they developed. Our feedback helped inform the next version of the standard. PBX had meetings with terminal operators, port authorities, and engineering groups from California and equipment design experts from Canada and France to discuss challenges and share best practices. These collaborative meetings helped to clarify various aspects of the project design, vessel commissioning requirements, shore power connection, vessel mooring position, and protection and coordination requirements. As shore power systems for container ships that are compliant to IEC/ISO/IEEE 80005-1 are new to Canada, a work session at the annual meeting was dedicated to discussions on the approach BC Hydro will implement to provide power to these systems.

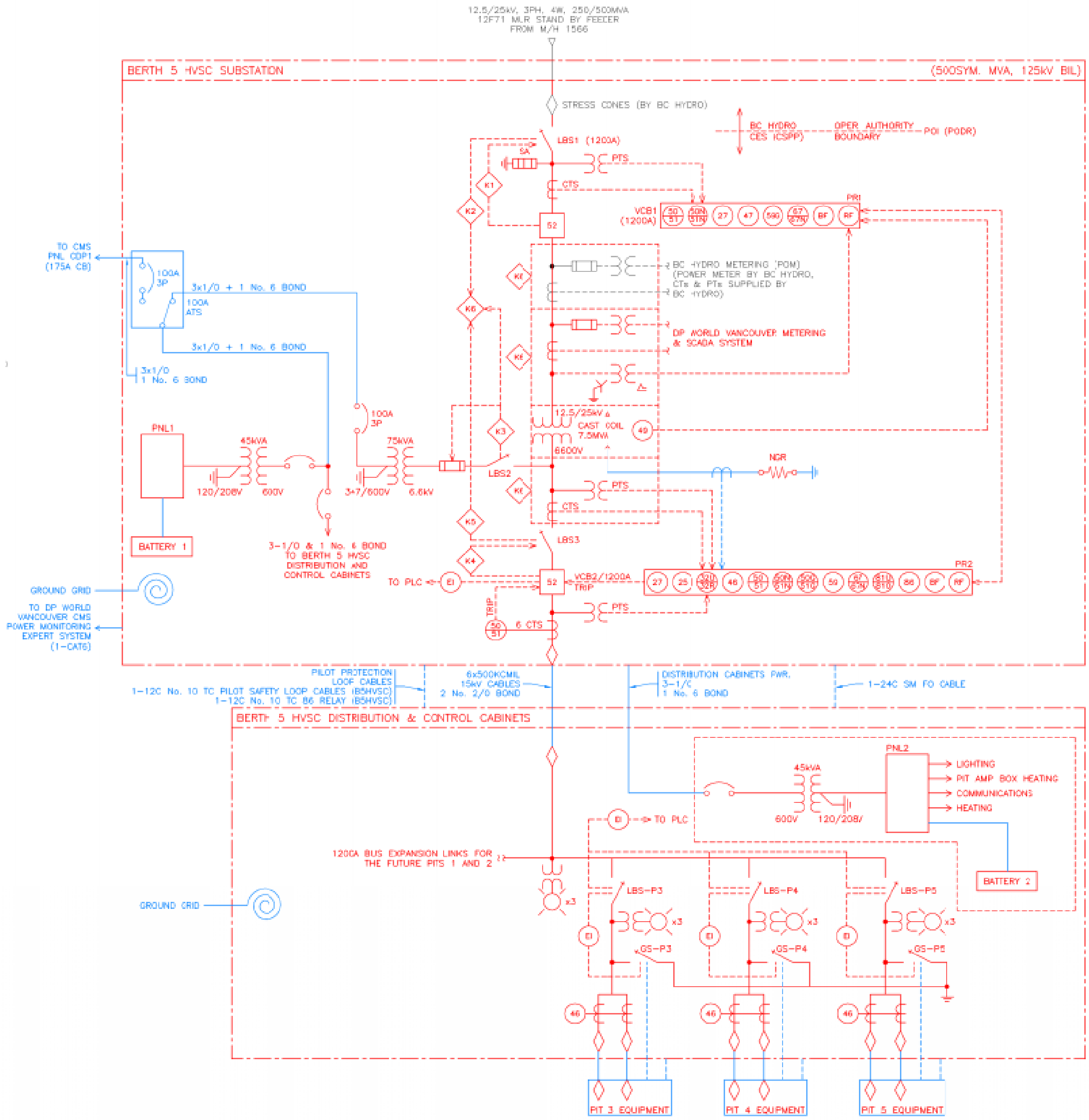
BC Hydro

In order to achieve uninterrupted power load transfer during the transition from vessel diesel generation to power supplied from the BC Hydro electrical grid, a Closed Transition Transfer (CTT) system has been implemented to allow for the temporary paralleling of the vessel diesel generators and the BC Hydro utility power. The CTT system is intended to be operated automatically, and as per IEC/ISO/IEEE 80005-1, the system will automatically synchronize and transfer the load between the shore power supply and the vessel power supply after their connection in parallel. The CTT will disconnect one of these sources if the defined maximum transfer time limit is exceeded.

As the first container vessel shore power system designed to international standards in British Columbia, this installation presented a new and unique interconnection requirement for BC Hydro. PBX worked closely with BC Hydro to develop new interconnection requirements for container vessel shore power systems being installed within the province. In July 2017, BC Hydro released an addendum to their *Interconnection Requirements for Power Generators*, with specific provisions for terminals supplying ships capable of running in parallel with BC Hydro. This amendment was the direct result of PBX's collaboration with BC Hydro, and it paves the way for other terminals in British Columbia to pursue shore power installations.



Shore Power Receptacle Outlet



Shore Power System Single Line Diagram

System Automation

Safety is of upmost importance and is a guiding principal for all designs prepared by PBX. When designing the Centerm Shore Power System, we looked for ways to improve the safety for operations personnel involved in the connection process. Typical systems involve the manual actuation of switches by an operator. This exposes them to potential arc flash hazards. In addition, receptacle pit lids are not secured and the high voltage cables can be accessed while the system is energized; again, exposing personnel to a potential arc flash hazard.

The shore power system designed and installed at Centerm is the most modern system installed in the world to date. The only physical labour task required for the operation of this system involves the connection of the vessel plugs into the shore receptacles. All other operation tasks are fully automated and controlled from the Human Machine Interface (HMI) screen. The equipment status checks are conducted from the HMI screens via field sensors and CCTV cameras. Interlock keys have been removed and replaced with maglocks and proximity sensors. There are several different layers of safety implemented throughout the shore power system at Centerm, including safety loops, direct communication with the vessels, equipment status checks and control via PLC, direct electrical interlocks, and an additional safety control relay system. These design elements differentiate the Centerm Berth 5 Shore Power system from and other similar systems, and results in a system which is straightforward, safe, and reliable to operate.

BENEFITS

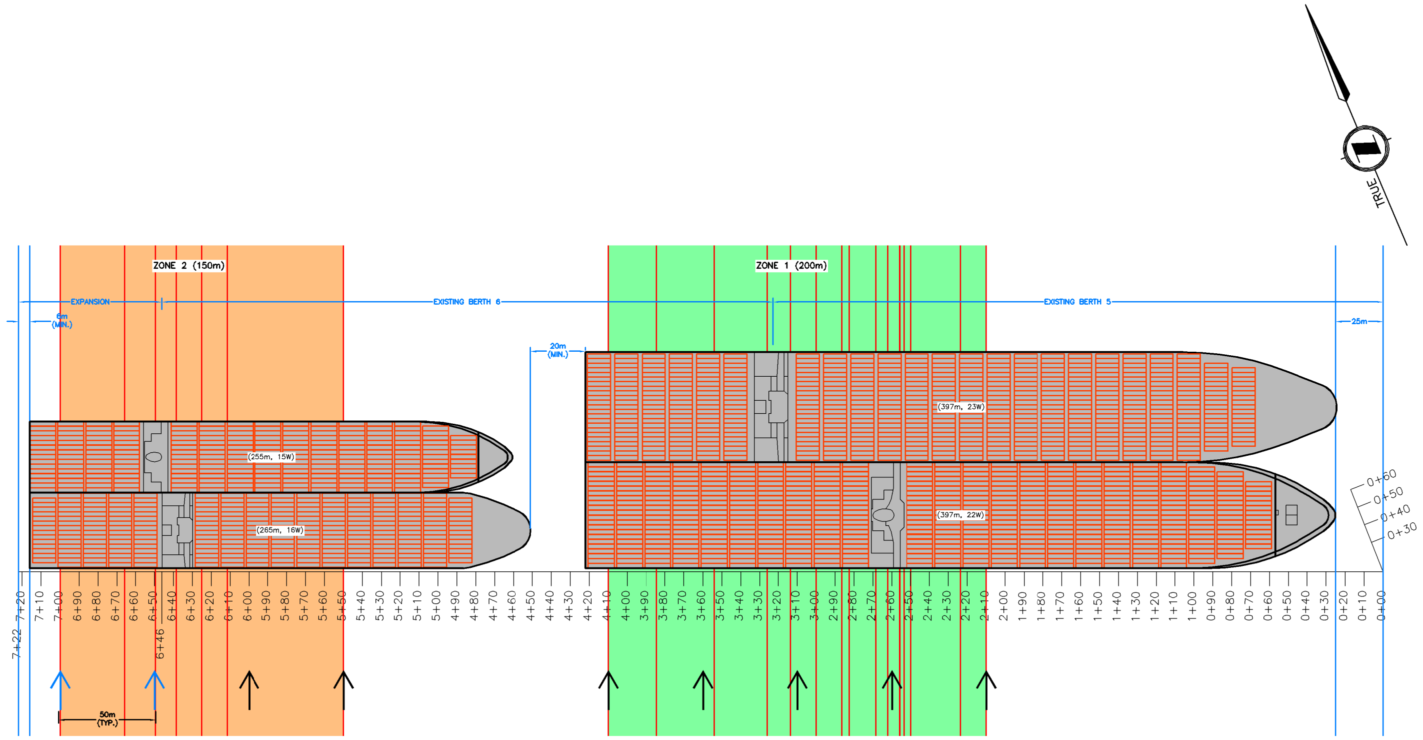
- **Reduces air pollution in Vancouver**
- **Improves air quality for community and terminal employees**
- **Reduces noise impact by 5 decibels**
- **Improves terminal productivity - no need to stop operations due to vessel fumes and in-shore winds**
- **Financial benefits - energy from diesel generators is more expensive than electrical energy from BC Hydro**

The benefits of the Centerm Shore Power System are significant – shore power eases the impacts of growing Canadian trade on the local community by eliminating greenhouse gas emissions, criteria contaminant pollution, and generator noise associated with the auxiliary engines of container vessels at berth.

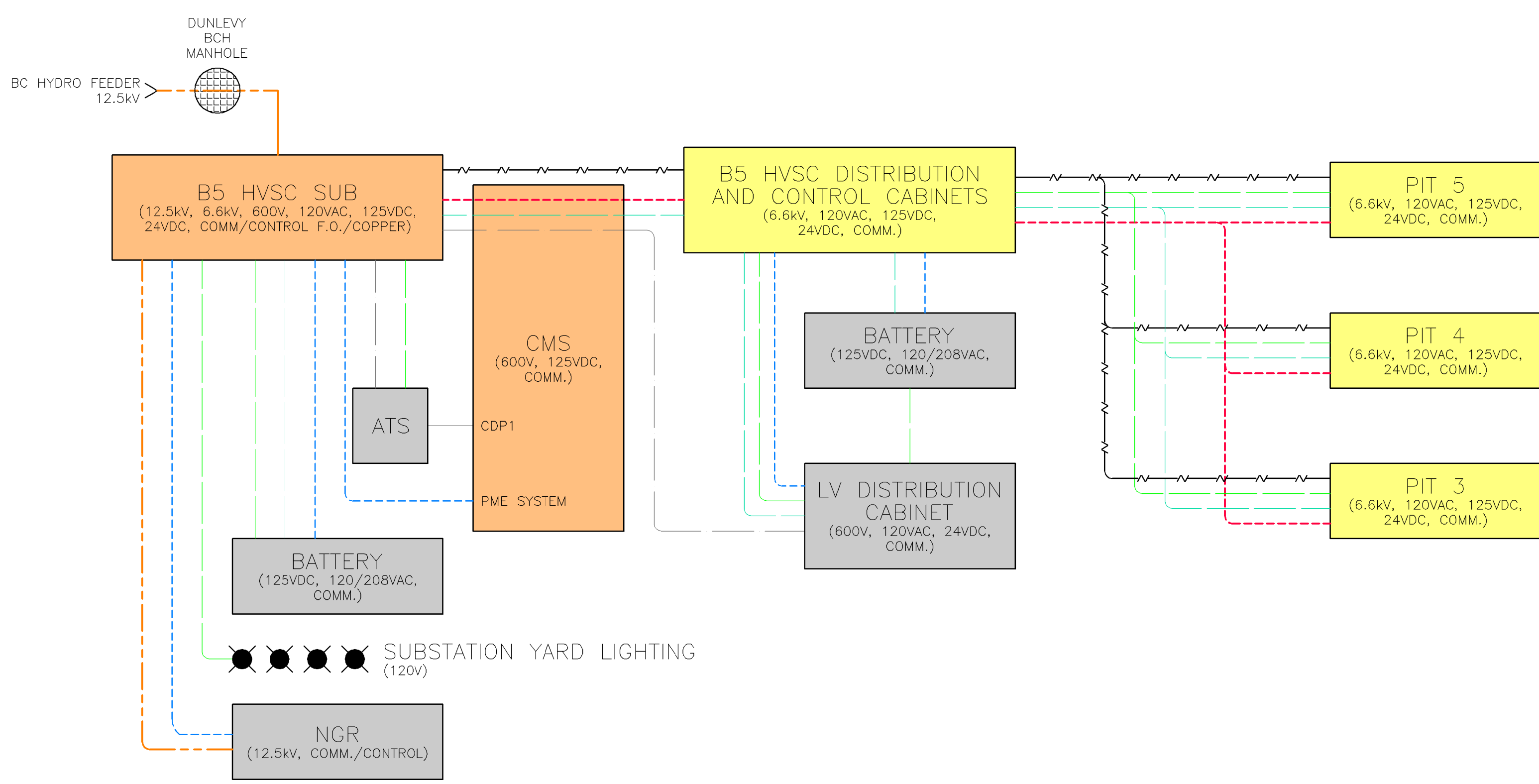
Vessels are powered from BC Hydro's clean electrical power grid, resulting in a reduction in sulphur oxides, nitrous oxides, and particulate matter. In April 2016, BC Hydro announced that 98.3% of the power they generate comes from clean or renewable resources.

Each container ship connection to the Centerm Shore Power System is estimated to avoid greenhouse gas emissions in excess of 95 tonnes for a representative 8500 TEU (Twenty Foot Equivalent Unit) capacity vessel at berth for 60 hours. If a potential 75 vessel connections are made in a year (which represents the number of ship calls known to be shore power capable visiting Centerm in 2016), that equates to 7,125 tonnes of gross carbon dioxide equivalent. To put the reduction in emissions into perspective, that is the equivalent of removing approximately 1,800 passenger vehicles from Vancouver's roads for one year. As a result of more vessels being provided with shore power connection infrastructure and the continuous growth of vessel sizes, these projected reductions are anticipated to increase proportionally.

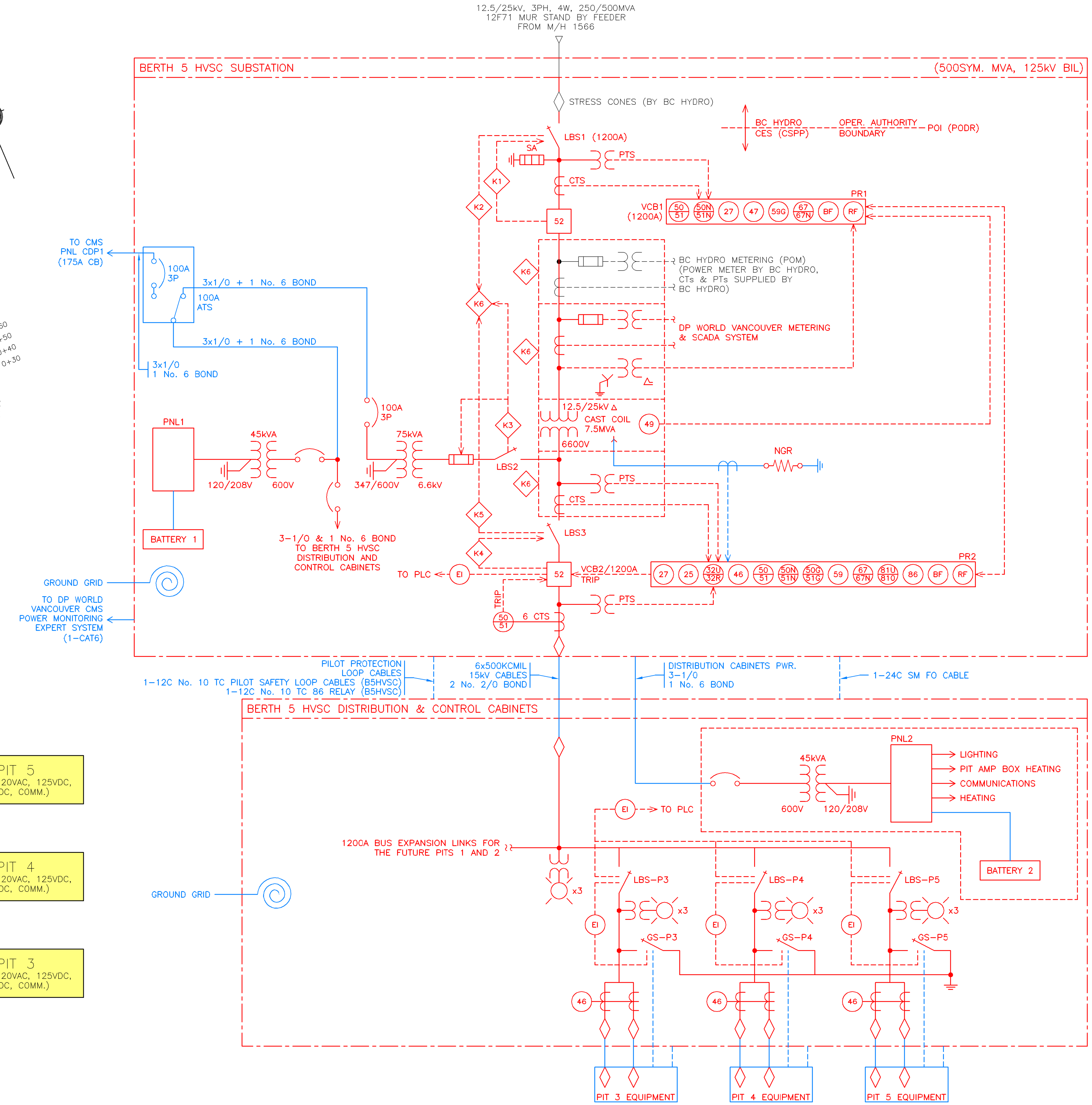
The Centerm Shore Power System is the first of its kind in Canada. It serves as a model for other Canadian terminals considering shore power, supports Canadian green energy goals, attracts ships with shore power capabilities, and provides an extra incentive for unequipped ships to install shore power systems. It is an industry-leading made-in-BC solution that applies local engineering innovation and expertise to overcome a difficult challenge, positively affecting our natural environment and the people of BC.



BERTHING STUDY



BLOCK DIAGRAM



SINGLE LINE DIAGRAM

Rev.	DATE	ISSUE / REVISION DESCRIPTION	DESN	QC	QA
–	180131	Submitted for Canadian Consulting Engineering Awards 2018	PBX	DB	AC

CLIENT: PORT of vancouver

PROJECT: VFPA CENTERM TERMINAL SHORE POWER PROJECT

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TITLE: CENTERM SHORE POWER

SCALE	PROJECT NUMBER	DRAWING NUMBER	REV.
AS SHOWN	–	–	–