High Voltage Pad-mount Transformer – Technical Discussion

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With Contributions From

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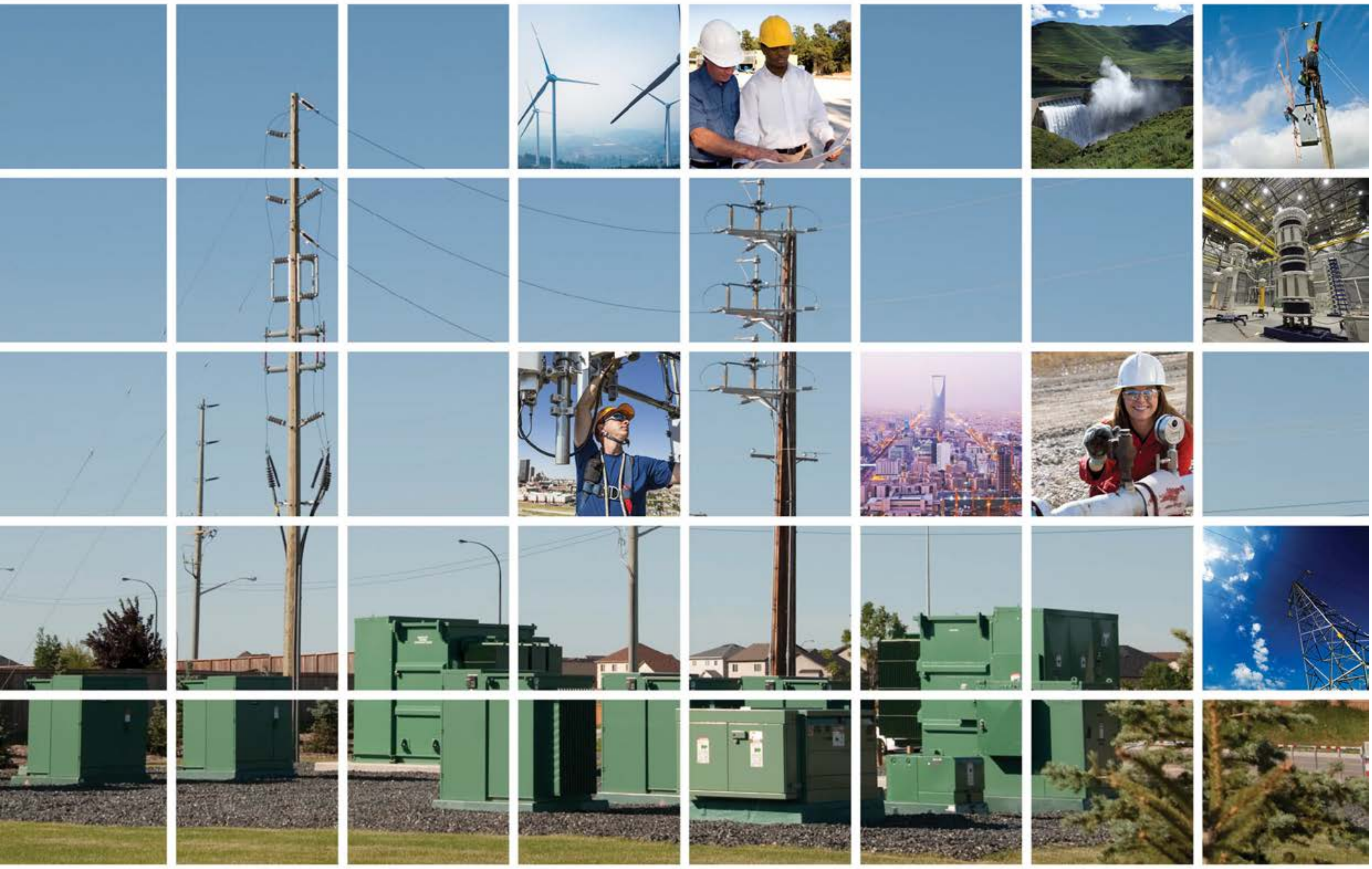

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Contents

Glossary

MH	Manitoba Hydro
HV	High Voltage
MV	Medium Voltage
TR	Transformer
IR	Infrared Radiation
DGA	Dissolved Gas Analysis
OEM	Original Equipment Manufacturer
CLF	Current Limiting Fuse
PRD	Pressures Relief Device
XLPE	Cross-Linked Polyethylene
EPR	Ethylene Propylene Rubber
ONAN	Oil Natural Air Natural

1.0 Executive Summary

As of 2017, Manitoba Hydro (MH) has installed over 105 High Voltage Pad-mount Transformer (HVPT^{TM})'s stations throughout it's Distribution System; powering residential and industrial customers including mining, data centres and oil companies. The HVPT^{TM} station has a capacity of up to 20 MVA and at voltage levels up to 138 kV. Using dead-front cable terminations that are shielded and grounded, the HVPT^{TM} station provides the same level of public safety as standard 35 kV and below pad mounted transformers situated in residential front yards of North America

The conceptual perception for implementing the HVPT^{TM} is that it may cause significant changes to distribution standards and transformer reliability concerns. These were the same concerns staff at MH initially had. In reality, nothing fundamentally has changed. The HVPT^{TM} has the same core and coil of a traditional open bushing power transformer and the HVPT^{TM} has proven to be a very reliable transformer.

What we are seeing at MH is with a more modular distribution system architecture, electrical service outages are limited to the size of any particular HVPT^{TM} load increasing redundancy and reliability. These factors are in addition to the added reliability of the HVPT^{TM}'s, reduced ongoing maintenance costs, and capital cost savings for new and replacement substations. By assessing all these benefits over a conventional substation's design, installation, long lead times, and cost constraints, the hesitation and resistance has waned and HVPT^{TM}'s have become the design of choice for distribution substations within MH.

Designed to expand based on customer requirements, the small foot print and low profile associated with the HVPT^{TM} substation has led to easy acceptance from the public, making it the perfect solution for growing loads with a developing community, large plant or campus-related organization, or city.

Manitoba Hydro has seen the changing trend in how utilities are developing and building Transmission and Distribution stations as utility operations and population dependency evolve. The move towards high voltage, cable connected dead front equipment is set to continue and expand. Almost 20 years since the first installation, Manitoba Hydro continues to reap the benefits of implementing the HVPT^{TM}, achieving notable improvements towards safe, economical and secure energy.

2.0 Introduction to Issue

When Manitoba Hydro decided to pursue a new approach for expanding, upgrading or replacing their existing distribution system using their distribution system more efficiently, the innovative result was the HVPT™ substation.

Manitoba Hydro's collaboration with Partner Technologies Incorporated (PTI) began in 1999 when MH staff initiated the idea of distributing electricity to surrounding areas using a Compact High Voltage (72kV & 115kV) Pad-mount Transformer (HVPT™). A concept was quickly designed and utility patent registrations were secured in Canada and the U.S.A.

The initial model incorporated a metal enclosed live front design, rated at 5 MVA and 72,000 Volts; that MH installed in North East Winnipeg. The installation freed up capacity on the fully loaded 25 kV system and avoided the significant costs that would have been associated with a conventional distribution station. The ability to tap off existing higher voltage lines located closer to the load, results in line loss savings. Applications of this design have included servicing significant customer loads, replacing aging rural stations, servicing loads in remote areas, and supporting medium voltage networks in areas with limited capacity.

Today, the live front design has been changed to a dead-front design. Currently MH deploys the HVPT™ Substations in many different ways. From modular designs with scaling capacity to radial feeds for large industrial customers or small communities. MH has seen great savings in both capital and maintenance budgets as well as outages because of the reliability associated with the HVPT™.

3.0 Lifecycle Discussion

Design Requirements

The HV pad-mount distribution equipment is completely metal clad, dead front cable connected and locked with two stage tamper-proof locks. By design, the installation is extremely safe with a high degree of security and resiliency against severe weather. To improve aesthetics and reduce footprint, copper theft and site maintenance, a traditional bonded security fence is not used.

The MH HVPT™ has opted for a simple transformer design that relies on stand-alone distribution (i.e. secondary-side) voltage regulators rather than a transformer-integrated on-load tap-changer for voltage regulation. This eliminates the possibility of arcing by-products contaminating the transformer main-tank oil and allows for a much lighter transformer with minimal maintenance requirements. Pad-mounted reclosers with modern, sophisticated electronic protection capabilities monitor and protect the transformer from the downstream distribution system while recently developed, 69 kV and 138 kV current limiting fuses ensure that the transformer is protected from damage caused by high fault currents.

To protect the public and staff, an engineered grounding system must be designed and installed to control touch & step potential voltages during normal and fault conditions. To accomplish this design, electrical testing of the local ground conditions in the planned station area is completed. Considerations of changes to local ground condition due to seasonal climatic patterns are also analyzed. With understanding of the available system fault levels and operating speeds of the protection systems, a grounding system can be designed for the installation to limit standing and transient touch and step potentials to safe acceptable levels. These gradient control grounding systems are installed below grade, safe from theft and require zero maintenance. Isolation stone at the installation can be selected from a variety of materials provided finished product meets electrical resistivity specification.

Transformer equipment design integrity has been proven through successful short-circuit/fault testing by an independent laboratory, zero in-service transformer failures since installations began in 2001. Utility has experienced of over 15 known through-faults on the system to date without TR damage.

To greatly reduce fault energy experience by the TR and associated equipment, a CLF scheme has been specially designed and tested, this setup is utilized in system areas where expected fault levels over 4 [kA] will be available. CLF fuse design is suitable for areas up to 20 [kA], and are paramount in reducing the risk of tank rupture during a fault. TR design also includes an internal PRD, which relives pressure during event internally to the enclosure. Provided assessment of risk of oil spill is acceptable, and given the low TR volumes, oil containment is not normally required.

TR design utilizes a high-grade quality core steel, improving efficiency and reducing noise levels to 60 [dB], very well adapted to urban & rural operating environments.

Civil Construction

Civil construction requires that equipment foundations be arranged to facilitate cable installation and future equipment maintenance and replacement. Multiple options exist to designers and users including concrete or grillage for the HVPT and fibreglass or timbers for the switchgear, reclosers and station service transformer. When considering foundation type, a designer must consider future options for TR replacement as well as cable protection.

HV transformers are designed to be moved by either crane or to slide onto foundations for maximum site and storage flexibility.

The cables will be installed below the ground, in conduits that are arranged between the equipment bases. Electrical conduit depths, angles and termination locations in foundation is important to avoid cable damage during installations and facilitate cable termination work.

Conduit size and radii of all bends and coils must be carefully considered and arranged to avoid damage to cables during install, while allowing for future replacement.

Electrical Construction

Modern dry type cable accessories are available for XLPE & EPR cable systems up to 138 kV, they require zero oil or ongoing maintenance for live front air insulated and dead front plug type designs.

Moving away from traditional station building systems to HV underground cables requires a large shift in workforce skill sets, training, tools & safety rules. An example would be utility safety rules related to underground cable grounding and isolation. Requirements along with approved visual opens will have to be reviewed to understand equipment and tool requirements associated with construction and maintenance tasks of HV pad-mount installations.

The success of the project will rely heavily on the quality of the HV cable terminating work. Training & tool requirements for the HV cable work will require major investment if the utility does not have a strong power cable trades background, this may include the requirement for manufacturer assembly training & certification, or employ of certified contractor.

Specialty HV underground cable contractors are available for hire, depending on previous experience and OEM qualifications, the utility may want to consider requirements for cable crew to be trained & certified on required cable accessories by the OEM technicians before construction of installation.

Third party inspections or OEM factory inspectors are also options open to utilities to ensure quality work. If the utility does not maintain U/G HV expertise, an emergency response contract should be considered with a contractor, considering that specialized crews move internationally and quick response could be an issue.

Time of year for construction is also a consideration as higher voltage cables cannot be manipulated below -10°C

Flexibility, metallic shielding size and design of selected power cables must be carefully considered to ensure acceptable workability of during installation and terminating work. Specialty tools will be required; storage and maintenance of these tools need to be considered.

Commissioning

Equipment received by the utility should be acceptance tested after receipt, and normally is also completed on equipment after shipping to the installation. Transformers, regulators, switchgear and protective devices are tested for insulation assurance as well as proper operation.

HV & MV cable systems can be commissioned with over-potential withstand testing after termination, but can prove to be very costly and practically time prohibitive, the utility or user will have to balance these costs and risks with confidence and experience of employed cable trades.

Maintenance

The HVPT™ is a simple transformer design that has separate distribution voltage regulators rather than an on-load tap-changer for voltage regulation. This eliminates the possibility of arcing by-products contaminating the oil, and allows for a much lighter transformer with minimal maintenance requirements. Transformer connections are all dry-type dead front cable connections that do not require cleaning or any ongoing maintenance. In this arrangement, transformer only requires time based DGA oil samples to be drawn. Because of the design of the HVPT™, this DGA oil samples can be taken while energized. Utility experience has shown DGA to be a useful predictive indicator for equipment condition monitoring, allowing utilities to avoid failures and complete repairs and/or replacements on planned outages.

Utility experience has shown that IR scanning to be an effective tool in detecting installation defects in medium voltage dead front cable accessories and apparatus bushings before failure. Experience recommends considering an increased scanning frequency for first two years after a new installation commissioning, moving towards an annual scan after this period, preferably during known periods of elevated loading.

HV cable accessory components have shelf lives, which need monitoring with a time base replenishment system set up for spares. Most MV cable accessory do not have these issues.

If fuses employed for primary TR protection, storage of on-site spares needs to be carefully considered to avoid moisture absorption.

TRs and associated equipment such as regulation, switchgear, protective devices, cable & accessories are all designed to be modular and easily replaceable, spares carrying costs and risks are optimized by equipment standardization.

Operational Advantages over Conventional Substation

The HVPT™ Substation has several operational advantages over conventional substations. Having no open bushing and minimal overhead conductors eliminates the risk of outages due to wildlife. With a conventional substation utilities have to fight the constant battle of birds nesting in the steel lattice superstructure, or wildlife climbing on the transformer and bridging the two phases. In some countries, the utility requires transformer manufacturers to design transformers with bushing spacing larger than the typical wingspan of their local wildlife. In a HVPT™ station, this is not necessary.

The HVPT™ is a dead-front transformer that safely allows for inspections and oil samples to take place while energized. The HVPT™ Station has is no exposed conductors. With the rising cost of metals like steel and copper many utilities are experiencing theft from their substations. The primary risk is with visible conductors. Most of the time this is grounding conductor that brings additional safety and outage concerns to the station. With an HVPT™ Station, there is no above ground portion of the grounding grid. All grounding points are internal to the pad-mounted devices. The only external conductor is on the overhead to underground transitions. MH has had no cases of copper or ground wire theft on any in service HVPT™ Station.

4.0 Study Cases

Modular Expansion

MH evaluated options to service a load of 70 to 100 MVA to a new subdivision of Winnipeg, which would house over 13,000 homes and businesses. Developers expect subdivision to take between 18 and 30 years to complete. To service this load growth, MH narrowed five options to three scenarios that were technically feasible:

- Expand an existing 115 kV - 25 kV substation by adding an third 115 kV – 25 kV, 60/80/100 MVA transformer.
- Construct a new 100 MVA 115 kV – 25 kV substation in the Waverly West area.
- Sequentially install 10 MVA, 66 kV -24 kV HVPT™ substations as loading requires.

MH examined all three of these scenarios in detail, for expanding the 115 kV substation, the main benefits MH identified were:

- the increased capacity at existing substation being available to other feeders
- all the equipment is at one location, with no need for easements
- low visual impact as there would only be a change in the existing substation which the public would not really notice

The main disadvantages identified were:

- high initial upfront costs
- risk of stranded assets

For a new 115 kV substation, the advantages and disadvantages were similar to the expansion option, however with a new substation there would be a high visual impact to the public as a new substation would have to be built taking up a space of approximately 5 acres.

The HVPT^{TM} substation approach suggested installing up to 12 – 10 MVA HVPT^{TM} Substations, allowing a firm limit of 110 MVA.

Advantages of the HVPT^{TM} approach are:

- Increased utilization rates
- Ability to quickly adjust to Load growth
- Almost no risk of stranded assets

MH requires a Firm Limit for it's system which is equal to the supply available if an asset goes down. In the HVPT^{TM} scenario, with 2 – 10 MVA HVPT^{TM} substations installed it gives a Firm Limit of 10 MVA and a utilization rate of 50%. For each 10 MVA HVPT^{TM} Substation installed on the system the Firm Limit goes up by 10 MVA and the utilization rate goes up accordingly. If all 12 – 10 MVA HVPT^{TM} Substations were installed the Firm Limit is 110 MVA with a 91.67% utilization rate. It would be impossible to see utilization numbers like this in a conventional substation. The Conventional Substation Expansion for example, would only ever see a 66.67% utilization rate because even though the capacity of the station would be 300 MVA the Firm Limit would be 200 MVA.

Installing the HVPT^{TM} Substation in 10 MVA blocks reduces the risk associated with slow or stopping load growth due to economic climate. Once the load demand increases the HVPT^{TM} substation installations can resume. At any point in time, the entire system only has a 10 MVA block in excess of load requirements. This also shows the minimal risk of stranded assets. If a 100 MVA substation was installed with the expected 18 to 30 year timeframe for Waverly West to develop, the capital investment is tied up for 18 to 30 years before the revenue is realized.

The disadvantages to the HVPT^{TM} Substations identified are:

- Possible negative visual impact
- Potential training required.

While negative visual impact is identified as a potential disadvantage, MH has not seen the public pushback they had expected with the HVPT^{TM} Substation. Because the HVPT^{TM} substation has no external fence, no steel superstructure, and typically, no structures associated with it, the profile of the substation is quite low. MH selected locations where residential fencing or vegetation would reduce the visual impact. On occasion MH undertakes landscaping to reduce the visual impact.

When MH suggested this solution, the HVPT^{TM} was still a relatively new technology, and they were concerned that additional training was required. The training that MH identified was how to conduct switching on a HVPT^{TM} installation. MH personnel now receive this training as an extension to the typical switching training program.

Ultimately, MH selected the HVPT^{TM} substation for the new subdivision system expansion because of cost. MH conducted a Net Present Value(NPV) analysis on the three solutions presented above, looking at the costs with between an 18-year Rapid Growth, a 30-year Slow Growth and a 30-year Slow Growth with a

5-year stall. MH determined the NPV of the HVPT™ substation vs the substation expansion/new substation was 62% and 50% respectively.

Radial Load Feed

A client required a solution to supply a growing load off a radial 66 kV transmission line. The expected load was to be approximately 20 MVA over the first 15 years of service. The client investigated two potential solutions:

- Construct a new 15 MVA 66-24.9 kV traditional steel substation with two 15 MVA transformers.
- Construct a new 66-24.9 kV HVPT™ substation with two 10 MVA HVPT™ transformers.

The client asked for a comparison of both of these scenarios. A cost-benefit analysis of both scenarios was presented to the client. The analysis looked to compare the two solutions:

Categories Analyzed	HVPT™ Substation Vs Traditional Steel Substation
Lead time From Inception to Operation	HVPT™ – 26 to 30 weeks Traditional – 52 weeks +
Engineering Time	HVPT™ – 8 to 10 drawings for full installation Traditional – 50+ drawings
Protection and Control	HVPT™ – Simple Fuse Design, Less monitoring and control Traditional – More control CT's, and PT's with breakers.
Reliability Factors	HVPT™ - Wildlife, Equipment Failure, Tamperproof, Weather Resistant Traditional - Industry Experience
Environmental Footprint	HVPT™ – Smaller footprint, can employ Fire resistant and environmentally friendly fluids, can incorporate an oil protection system. Traditional – Larger footprint, Oil protection system design necessary, on site dressing and oil required.
Maintenance	HVPT™ – Yearly Oil Sampling and Visual Check Traditional – Bushing Maintenance, Oil Check, Fence, Security, Grounds, Wild Life Activity.
Safety	HVPT™ – Compact, Tamper-proof and weather resistant enclosure, grounding designed to prevent injuries to humans and wildlife, no above ground live conductors Traditional – Fencing required for public safety,

Emergency Replacement	HVPT^{TM} – MH was willing to loan it's replacement HVPT^{TM} to the client in case of a failure of client owned HVPT^{TM}. Traditional - None
Aesthetics	HVPT^{TM} – Smaller presence in the landscape, not as vertically visible. Traditional – Steel-superstructure can be undesirable
Estimated Cost (Engineering, Procurement, Construction, Life-Cycle Maintenance)	HVPT^{TM} between 3.0 - 3.6 M CAD Traditional between 5 - 6.5 M CAD

The biggest concern for the client was the willingness to not monitor the HV substation, and instead do monitoring of the low side only.

5.0 Technical Specifications

Transformer

The HVPT^{TM} does not change how voltage transformation occurs, it changes the way a high voltage transformer is connected to the system. Design features incorporate the ability to ship on a standard trailer completely assembled. This eliminates any onsite transformer dressing and oil processing. Installation or removal is easy as the design allows both HV and LV cable terminations to be left in place.

Connections and neutral configurations

- Delta – Wye: Low voltage neutral is brought out inside the LV compartment to a fully insulated X0 bushing with removable ground strap. Alternative X0 bushing can be brought out through a fully insulated deadfront grounding elbow.
- Wye – Wye: High Voltage neutral is brought out to an H0 bushing inside the primary compartment. The low voltage neutral is brought out to an X0 bushing inside the LV compartment.
- Wye – Delta: The neutral is brought out to an H0 bushing.
- NGR – an NGR can be mounted on the HVPT or as a stand alone equipment.

High and Low Voltage Bushings

- High voltage bushings shall be deadfront Pfisterer type suitable to accept Pfisterer connex separable connectors rated up to 145kV, 650kV BIL.
- Low voltage deadfront integral bushings up to 900A deadbreak.

Tank/cabinet features

- Bolted tank cover with gasket stops for tank access complete with tamper resistant flange
- Sealed tank construction. Units are supplied with a blanket of nitrogen gas or certified dry air
- Bolted cooling radiators complete with tamper resistant flange
- Three point latching doors with stainless steel captive pentahead bolts for tamper resistant security and provision for padlocking
- Removable sills to assist installation and removal when skidding and rolling. Ability to leave cable terminations in place
- 4 lifting lugs or jacking steps
- Stainless steel door hinges
- Tamper resistant construction is provided in accordance to IEEE C57.12.28 Valves/plugs
- Two inch upper vacuum connection
- One inch top filter press connection
- External one inch combination drain valve with sampling device in a tamper resistant protective cover
- Pressure relief device operates at 70kPA with oil flow directed to the ground. This occurs within the metal HV compartment not into publicly accessible space

Nameplate

- Stainless steel nameplate and connection diagram
- Can include any information required by the client

Core Construction

- Three legged, mitred step-lap core steel construction
- Cores are manufactured with grain oriented silicon steel. Many grades are available to optimize core loss efficiencies and reduce noise levels
- Epoxy bands and dowels are used on legs to give more support to core

Coil Construction

- Circular wound coils to minimize stress developed by short circuits
- Coils are wound using high grade copper conductors

Core & Coil Assemblies

- The core and coil assemblies are clamped and braced using heavy steel to prevent distortion under short circuit conditions
- The assembly is designed to withstand short circuit conditions in accordance to IEEE C57.12.00
- Core and coil assemblies are dried using hot air convection ovens

Tanks

- The tanks are assembled and welded in house at PTI per the Canadian Welding Bureau (CWB) guidelines
- High strength laser cut steel is used to fabricate the tank
- All welds receive dye penetrant testing and inspection prior to painting

Tank Finish

- Bare metal is protected by a state of the art two part powder paint system
- After shot blasting the base metal to an SSSP-6 near white profile, a zinc-rich epoxy primer is applied. This is followed by a high gloss polyester finish coat to seal and provide ultraviolet protection
- The finish exceeds a 2000hr salt spray rating

Vacuum processing

- The transformers are filled under full vacuum with filtered and degasified insulating fluid

Insulating fluid

- Standard insulating fluid is an electrical grade mineral oil exceeding ASTM requirements
- Mineral oil supplied can also include an additive to inhibit oxidation if specified
- Alternative natural ester fluids such as FR3 Envirotemp are also available. These are fluids that can quickly biodegrade. FR3 has a fire point >300 °C. and is Factory Mutual Approved

Quality

The HVPT^{TM} is manufactured at PTI's 100,000 square foot factory located in Regina, Saskatchewan, Canada. The factory is registered to the latest ISO 9001 Quality Assurance Management System.

Factory Testing

Every HVPT^{TM} undergoes routine testing at PTI including the following:

- Insulation Power Factor
- Ratio/Polarity/Phase Rotation
- Resistance
- Applied Potential
- Induced Potential
- No Load & Load Loss
- Pressure Leak Test

Additional testing is available including:

- Short-Circuit Test

- Temperature Rise
- Noise Level
- Impulse

Service Conditions

The HVPT^{TM} is designed to be air cooled (ONAN). In accordance with IEEE C57.12.00, the ambient cooling air can not exceed 40 °C, and the average temperature of the cooling air for any 24 hour period can not exceed 30 °C. Please advise the factory of any unusual service conditions such as high altitude or climate conditions with high ambient temperatures. The transformer can be under in these conditions, but special design considerations may have to be made in accordance to IEEE C57.91: Guide to Loading Oil Immersed Transformers. The HVPT^{TM} can be adapted to different temperature conditions to meet the requirements of each country; In Paraguay for example, the HVPT^{TM} transformer to meet a 10 MVA rating would be the equivalent of an 11 MVA transformer under standard IEEE C57.12.00. Under emergency conditions, the HVPT^{TM} can be loaded up to 125% of the nameplate rating.

Protection

MH's version of the HVPT^{TM} has no on board protection. MH implements a dual fuse setup as melt matched coordinated expulsion and current limiting fuse(back up fuse) scheme. Ultimately protection is decided on a case by case basis. The HVPT^{TM} substation concept is about simplicity, so MH uses fusing because it is comparatively inexpensive, visual, and easy to replace. In higher voltage situations or places where there may be a sensitivity to faults other forms of protection such as circuit breakers or circuit switchers may be implemented.

HV Cable

MH uses solid dielectric cables with a heavy corrugated shield to maintain flexibility while providing robust mechanical protection, moisture barrier and fault current capability. These cables meet standard AEIC CS9-06: SPECIFICATION FOR EXTRUDED INSULATION POWER CABLES AND THEIR ACCESSORIES RATED ABOVE 46KV THROUGH 345 KVAC.

MV Cable

MH uses MV underground cable that satisfies CSA C68.5 - Shielded and concentric neutral power cable for distribution utilities. MH uses XLPE or EPR cables with a heavy corrugated shield to maintain flexibility while providing robust mechanical protection, moisture barrier and fault current capability, up to 1000 kcmil copper or aluminum.

HV Bushings

The Pfisterer Connex cable termination allows the HVPT^{TM} to be a Dead-front transformer. The Pfisterer Connex cable termination system is IEC 60840 compliant and allows for Dead-front connections up to 245 kV. The Connex termination is a dry type cable accessory that does not require oil or SF6 for assembly or operation; a dry well plug and play connection essentially turns the HVPT^{TM} essentially into a large-scale distribution transformer. If there is a problem in with the HVPT^{TM}, it can be “unplugged” and quickly changed out for a spare transformer in less than 24 hours.

MV Bushings

The MV bushings are dry-type separable bushings. The bushings limit the low side current to 900 amps for a single bushing, if additional current is required, parallel bushings can be installed. All bushing used meet IEEE 386: Separable Insulated Connector Systems for Power Distribution Systems Rated 2.5 kV through 35 kV.

Grounding

MH designs custom ground grids for each installation to meet or exceed the Grounding Design Levels stipulated in IEEE 80. MH gathers data on soil resistivity measurements, fault currents and clearing times were required to provide an accurate model. The ground grid design ensures that transferred potentials, touch voltages, step voltages, and ground potential rise voltages are designed to be within safe tolerances for the public, employees and equipment. By having a ground grid that is safe for these factors, MH is able to eliminate the need for fencing on the HVPT™ Substation. This is a significant cost saving as the utility does not need to tie the fence into the ground grid. Upon installation of the ground grid, MH completes a Fall-of-Potential measurement to confirm that the grounding systems meets expected performance.

HV Air Terminations

In MH, Underground Transmission Lines are rare, so a HVPT™ Substation involves a transition from Overhead Conductors to Underground Cables. For this transition, MH uses dry type assemblies. MH uses Cold Shrink style terminations for 69 kV, and push-on style terminations for 115kV and 138 kV. These terminations provide a safe and reliable transition from overhead to underground.

MH will then preform testing as outlined in IEEE 48 - Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV and IEC 60840 - Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) - Test methods and requirements to ensure that the installation is installed and operating properly.

MV Customization

MH strives for simplicity in the rest of the substation. Switchgear, voltage regulators and reclosers are all pad-mounted designs, meeting IEEE C37.60 and IEEE C37.74 respectively. The different pieces are selected based design needs. MH uses air insulated switchgear, GIS (SF6 insulated), or solid dielectric switchgear equipment. All of these can be automated or manual. The GIS and solid dielectric switchgear can be outfitted with controls and monitoring for “Smart Grid” applications. By choosing a switchgear that fits properly for each situation, the HVPT™ substation becomes a viable solution for many different products.

6.0 Sample Single Line Diagram