New Underground Economical Distribution System Direct Buried

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Introduction

A Submersible Solid Insulation Distribution Transformer (SSIDT) was developed jointly by ABB Canada and Hydro-Québec. It is corrosion free, without liquids or gases, water impervious, with adequate surge and load withstand. It is well designed for underground systems. This technology result to the development of an economic direct buried underground system where the submersible technology gives the full benefits.

Background

Many of the first URD installations were submersible. They quickly showed signs of corrosion and subsequent failure. Much of the industry then went to construction with pad mounted distribution transformer (PMT) and also to a small degree to dry transformer, sized for each residence. The dry-type transformers failed early due to poor overload and surge withstand. The pad-mounted transformer, in today's evolutionary design, represents the majority of new constructions, and except for some medium-term tank-wall corrosion problems, is experiencing a satisfactory service life. The violent failure mode in the oil insulated system, has been controlled by improvement of transformer tank strength for circuits with fault current capability up to 10kA and by the selective use of the current limiting fuses, either in the transformer or at the circuit entrance. It is now perceived, that the principal PMT disadvantage lies in the user objections to the aesthetics of the transformer profile, which is evident in front line construction. An unquantified further disadvantage is the potential for soil contamination in failure modes.

The SSIDT was developed to provide an opportunity for a fully submersible transformer that is thermally and dielectrically adequate.

Unique Design

The unique design of the SSIDT (fig. 1) features a solid insulation system and a composite-material outer shell. The electrical Insulation system is made of 100% solid materials and has no liquid or gas dielectric medium. It is comprised essentially of insulating paper and epoxy resin. The epoxy resin dielectric medium totally impregnates the windings and coats the magnetic core. The outer shell of the SSIDT is a composite of fiberglass, carbon fiber and epoxy resin. It is waterproof, corrosion resistant and requires no maintenance. It also reinforces the structure of the transformer.

SSIDT for URD Direct Buried Application

The SSIDT has the potential to replace the present day PMT to achieve an all-submersible system construction. The benefits of the all-submersible system include:

Figure 1
50 kva, 24940GrdY/14400-240/120V

BIL	125	KV	Length	21.5	In
IZ	3.5	%	Width	20	In
NL	130	Watt	Height	20.5	In
LL	250	Watt	Weigth	310	Kg

I. A corrosion free product *throughout* the service lifetime;
II. No sacrifice in loading capability, surge withstand or corona levels;
III. No visual pollution; Freedom of movement for people and vehicle;
IV. Performance immune to weather conditions;
V. Explosion resistant;
VI. Performance unaffected by solar heat;
VII. Elimination of soil contamination. (potentially no need to remove the old unit;
VIII. Economy of ***vault-less direct burial*** or adaptable to simplified innovative mini-vault construction;
IX. Potential for comparable or reduced total installed system cost;
X. Reduced sound levels.

The characteristics intrinsic to the SSIDT provide several opportunities to the designer:

- The primary bushing well(s) can be directly molded into the unit, eliminating the need for a separate part;
- Secondary cables can be integrated into the unit, eliminating the need for separate secondary bushings;
- Lifting and support brackets can be integrated in the outer shell providing a completely corrosion free unit.

One version was created with a fiberglass outer shell suitable for direct buried applications (fig. 2). They can be installed in any position and has the benefit of being light and very compact.

Test Behavior

The SSIDT was subjected to a series of routine, type and special tests. The special tests comprise:

- Demonstration Test for Direct Buried Transformer
- Heat runs and Overload tests
- Short-circuit Withstand
- Impulse Withstand
- Low Temperature and Thermal Shock
- Internal Fault Withstand Performance

Demonstration Test for Direct Buried Transformer

Two 50 kVA units with fiberglass envelope were installed underground for a long-term demonstration. They are connected back to back with one unit directly buried in the ground and the other installed in a near by regular sewer pipe.

Figure 2

Fiberglass transformer installed in a regular sewer pipe showing connections and monitoring wiring.

The transformers are instrumented with thermocouples, voltage and current meters, as well as, sensors to measure the earth and backfill thermal resistivity. The direct buried transformer was covered with a mixture of sand, crushed stone and water. Then the installation was covered with soil and grass (see figs 3 and 4).

Figure 4

Transformer burial with native soil, gravels and sand

Figure 3

Two transformers connected back-to-back, one directly buried in the ground and the other in a standard sewage pipe. The transformers are presently energized at full load.

Heat-runs and Overload Tests

These transformers have been subjected to a series of heat run tests simulating normal and overload conditions. As an example, one overload test consists to apply 140% of the nominal load during 8 hours. The test was done following by a constant load of 70% and followed by a constant load of 100%. As can be seen on figure 5, at 100% load, the maximum temperature recorded by the thermocouple located between the low-voltage and the high voltage winding, at the center of the transformer, is 128°C which is well below the temperature limit of the insulated material, which is rated up to 200°C.

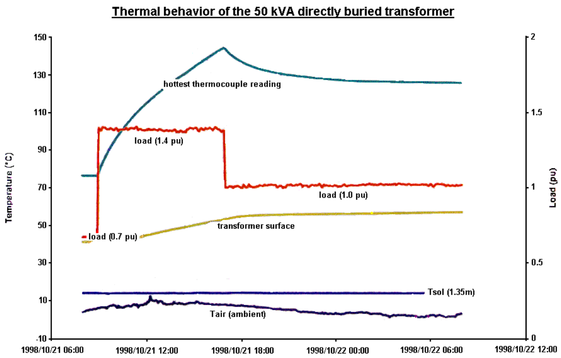

Figure 5

Similar tests were performed with different overload and duration following and followed by a constant load of 70% (see table beside). During these tests the maximum hot spot temperature did not exceed 145°C. The test units have been in continuous operation since April 98 except for one month shutdown where they were de-energized and soaking in wet soil for that period before re-energizing them successfully. The results evidenced adaptation to the operating conditions.

Overload (%)	Duration (Hours)
113%	24
133%	4
140%	8
154%	2
178%	1
200%	1

Short-Circuit Withstand

Short-circuit tests performed on SSIDT have shown that the only change in impedance voltage was due to the winding temperature increase after each short-circuit test. The impedance voltage measured before, during and after the short-circuit test were consistent and varied by less than 0.15%.

Impulse Withstand

Impulse tests performed on the SSIDT have shown that they can withstand repetitive impulse tests. For example the same 50 kVA unit withstood prior to the short-circuit test:

2 reduced waves at 60 kV, 2 chopped waves at 125 kV, 3 full waves at 125 kV and after the short-circuit test 2 full waves at 95 kV and 2 full waves at 125 kV. Impulse tests performed immediately following a heat-run test, confirmed that the SSIDT can withstand impulses at an elevated temperature. One unit withstood a total of 4 full waves at 125 kV while the transformer was at 92°C.

Low temperature and thermal shock

One transformer was subjected to five consecutive thermal shock tests in a climatic chamber as follows: 0°C, -10°C, -20°C, -30°C and –40°C. The test consisted to lower the transformer temperature until it reached test temperature. When equilibrium was reached, full voltage and 200% load were applied on the transformer under test for one hour (See Fig. 6). Partials discharges measurement made before and after each test have shown no change.

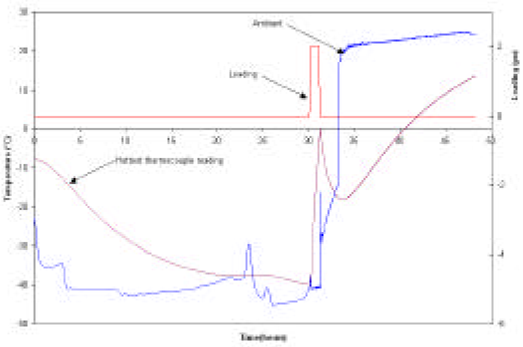

Figure 6
Thermal Shock Test at –40°C

Internal Fault Withstand Performance

Fault withstand tests have been conducted to a SSIDT prototype where an internal fault to ground was simulated using a fuse wire. Two consecutive faults were initiated, one at 8kA and the second at 10 kA symmetrical rms available on a 14.4kV circuit for one cycle. The tests have demonstrated that no flying parts and no fire would result from such conditions. Further, the fault did promptly reestablish on reapplication of the circuit conditions.

URD Mini-Vault Installation

The product is suited for a conventional loop feed system construction (see fig.7) that can include:

- Full use of separable insulated connectors well positioned for operating ease on conventional 3 and 4-way junctions;
- Secondary terminals and cables that include single and dual element fuse;
- System fault detection reporting to the utility dispatch center via the cellular telephone system, together with downstream "visible" fault detection at each transformer location;
- Installation without a primary fuse in each vault, since the failure mode is non-explosive. Alternatively, a polymer encased primary fuse can be installed at each transformer location or at the beginning of a loop.
- Lightweight mini-vault without bottom for easy installation.

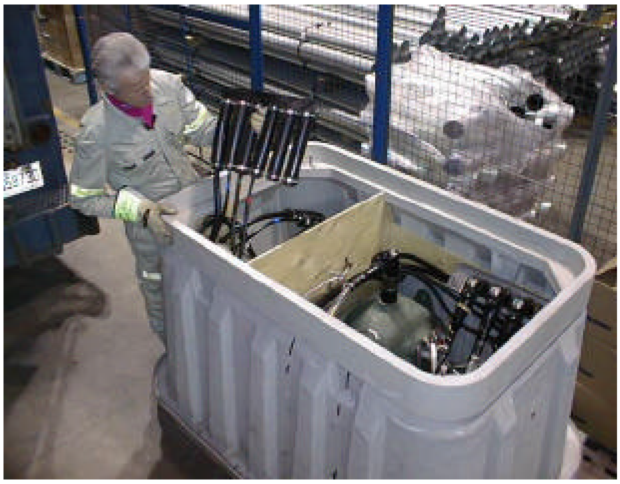

Figure 7
Mini-Vault construction showing Hydro-Québec system components

Conclusion

The totally submersible distribution transformer was first targeted as the ideal construction by utility engineers at the inception of underground residential distribution. It is believed that the commercial achievement of the SSIDT product provides an opportunity for the rebirth of an all-submersible URD system. Already, several North American utilities have started to install the Mini-Vault solution for their new and old installation on an economical base.