Retrofitting Secondary Substation Transformers

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Purpose

Retrofit projects are by their very nature undertakings that can become far more complicated, time intensive, and costly than might be expected or anticipated even by experienced field engineers. The intent of this article is to provide the reader with a level of insight into this process that will prepare them for the unforeseen complexities that can arise, and by doing so help minimize downtime, risks, costs, and frustration .

Introduction

Electrical engineers and transformer specialists would most likely agree that the installed base of secondary substation transformers placed in service during the 1970's and 80's are, generally speaking, approaching their designed life expectancy. There are also generations of transformers from earlier decades still in operation where owners have beat the odds for many years, and where probable failure becomes a significant risk. These transformers are most commonly either a form of dry type or liquid filled designs. The two types of transformer designs under discussion are depicted in figure #1 below.

Figure# 1

Liquid Filled | **Dry Type**

Mineral Oil, Silicone,

R-Temp®, Wecosol®, PCB

Envirotemp®, Beta Fluid®

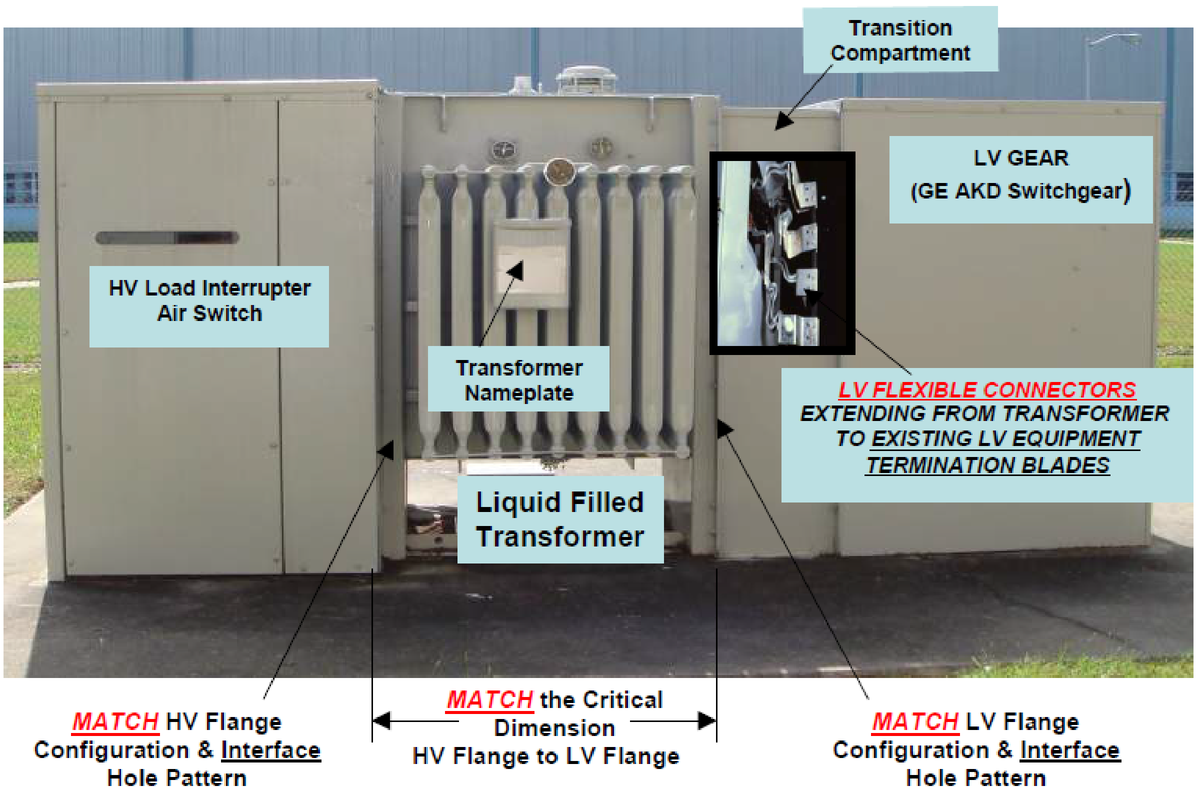
Standard Dry Type,

VPE, VPI, Cast Coil

The capacity of a typical secondary substation transformer is generally 500KVA through 3000KVA with a primary voltage of 5KV or 15KV and a secondary voltage of 480 or 208. These transformers can be found with air terminal compartments for cable connections to remote primary and secondary equipment or provisions for busway connections to same. In the vast majority of instances, however, these transformers are designed as an integral part of a "close coupled unit substation" that includes a fused primary switch bolted to the primary side of the transformer and either a switchboard or switchgear bolted to the secondary side. The focus of this discussion is on the design requirements, removal, and reinsertion of a transformer integral to a "close coupled unit substation". Figure #2 below shows a typical close coupled unit substation with the component labeled for identification.

Figure #2

Outdoor Liquid Filled Secondary Substation Transformer



It should be self-evident that the most efficient and least costly way to retrofit any transformer is prior to an unplanned outage when replacement often becomes a forced reaction to an immediate problem. With lead times on new transformers of up to 20 weeks, waiting until failure most often results in the owner looking for a used or surplus unit that may be available, but will generally be costly, of uncertain quality, a dimensional problem, and have less than optimal remaining life expectancy. When a project has high fixed costs in terms of rigging, electrical installation and testing, field modifications to transitions, and probably the cost of new flex connectors, installing a used transformer of questionable reliability and remaining life expectancy might not provide the owner the best outcome.

The most effective way to undertake a transformer retrofit is unquestionably on a planned and controlled basis. To develop an educated perspective on when to retrofit, it is suggested that owners implement an on-going inspection and maintenance plan to assess the reliability of installed transformers so that risks can be managed. The following is suggested as a general approach for documenting dry and liquid filled transformer health and status:

HOW TO ASSESS AN INSTALLED TRANSFORMER BASE

Liquid Filled Transformers - Routine Preventative Maintenance:

1. Routinely perform a Dissolved Gas in Oil Test and a Comprehensive Oil Analysis - by collecting samples from each transformer and securing certified tests results of each sample.
2. Over time plot the results so a tendency profile can be developed for each.
3. The critical gases to watch are as follows:
   a. Rise of Hydrogen (H_2) and Acetylene (C_2H_2). The elevation of these gases could provide early indication of arcing" within the transformer. These are combustible gases and if they are rising, quick intervention must occur.
   b. Aging liquid filled transformers will, at some point, produce increased levels of Carbon Monoxide (CO) and Carbon Dioxide (CO_2). As the insulation deteriorates due to heat and time in service, the insulating integrity is decreased putting the transformer at risk of failure. The owner should not delay replacement of a transformer as levels get closer to the total limit, 33,000 ppm. Values exceeding this level have proven to cause transformers to fail in the field.
   c. In concert with (a.) and (b.), above, routine maintenance should include recording load and oil and/or winding temperature readings. If the oil and/or winding temperature begin to increase, immediate attention should be given to cause.
   d. Less critical gases, important none the less, are Methane (CH_4), Ethane (C_2H_6) and Ethylene (C_2H_4) which generally reflect elevated heat levels due to electrical hot spots. Immediate Attention should be given to the cause.
4. Routinely monitor the top oil temperature – life expectancy of the insulation system is greatly effected by transformer temperature. A record of "winding temperature" vs. load provides data so the owner can develop "tendency profiles
5. Monitoring the nitrogen blanket on the transformer can provide indication of leaks that may allow moisture into the tank.

Dry Type / Cast Coil Transformers – Routine Preventative Maintenance:

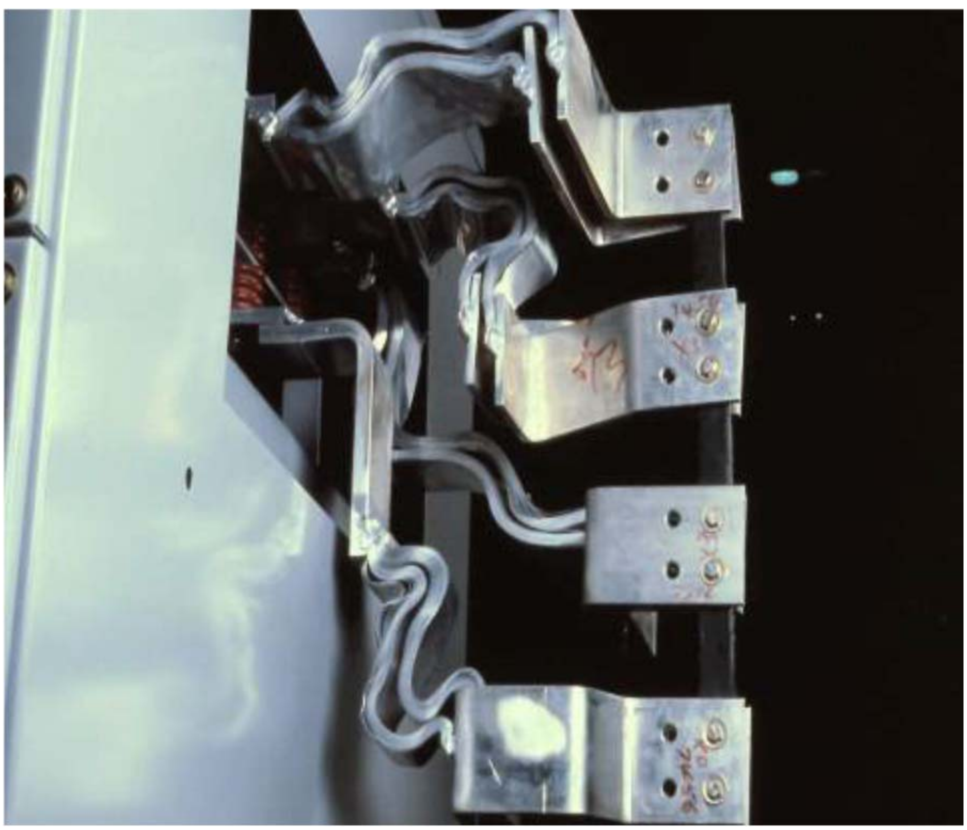
1. These transformers are open to air circulation for cooling designs. They tend to collect dust and develop cob webs over time from a normal environment. These transformers must be routinely taken off-line and cleaned. Instruction Books for these type transformers include cautions with recommendations to perform this maintenance yearly.

2. As the contamination accumulates, creep paths develop from phase to phase and phase to ground. If these paths connect to each other, the unit may fail.

3. Another enemy is moisture from the environment of location. The air should be controlled by removing excess amounts of moisture. Dry Type transformers can, over time, absorb moisture into insulation thereby putting unit in harm's way. This absorbed moisture deteriorates the insulation's integrity.
4. Routine maintenance should include a record of "winding temperature" vs. load. This provides data so the owner can develop "tendency profiles".
5. Routine Maintenance and analysis of recorded data will indicate when the transformer should be replaced."

When weighing the considerations involved in replacing a close coupled transformer the optimum situation for the owner would be to purchase an electrical and dimensional duplicate of that being replaced. Most high voltage connections from a primary switch to the coupled transformer are a simple cable connection. The connections between the low voltage secondary side of the transformer and the close coupled switchboard or switchgear are almost always either braided or ribbon type flexible connectors. A depiction of typical flexible secondary connectors is shown below in figure #3.

Figure #3



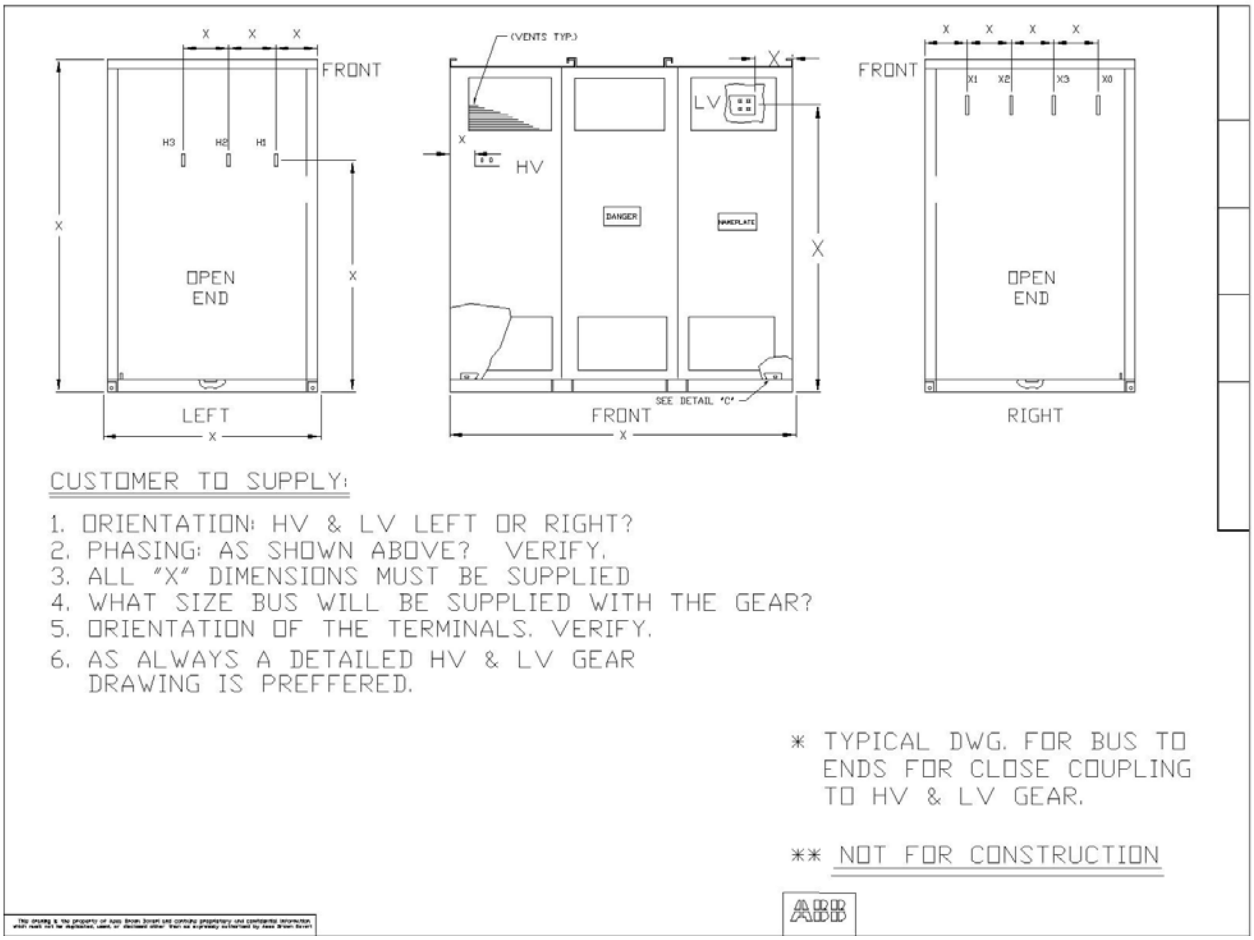
The best method for procuring a retrofit transformer is to obtain a copy of the original drawings for the high voltage equipment, transformer, and secondary equipment from the owner's records or the manufacturer. These records should show the existing voltages, ampacity, impedance, overall dimensions, high and low voltage flange pattern details, details for cable connections on the high voltage side, and details for low voltage flexible connectors. The availability of this information can greatly simplify the installation process and significantly reduce overall project costs. Often these documents may be unavailable and the owner is left to try to work with field measurements which may be close but inaccurate. When this is the case the owner should consider a replacement transformer with both the high and low voltage flanges undrilled. The installing contractor can field match to the existing high and low voltage equipment and drill through the transformer flanges to insure an accurate match. When the retrofit transformer has flange to flange dimensions that are close to the existing but not an exact match, it may be possible to slide the primary switch one direction or the other depending on the conduit locations and cable limitations. If the dimensional differences are too great the result can often be costly metal fabrication in field. There are times when the transformer being replaced may have physical dimensions that cannot be duplicated. In these rare instances, and where a dry type transformer is required, it may be possible to design a replacement that has been rotated 90 degrees to reduce the flange to flange width. Consideration also needs to be given to any restrictions that exist in the field such as columns, walls, doors, or other equipment that may impact the replacement transformers design and dimensions.

Owners often undertake a retrofit under the assumption that the existing secondary low voltage flexible connectors may be reused. Generally speaking, it is unlikely that the old low voltage connectors will match the new point to point details that will exist when a new transformer is supplied that is not built to the original design details. It should also be noted that the original flex connector have been in service for the life of the transformer and may have had their integrity compromised over time. Serious thought should be given to this issue during the planning stage to avoid downtime and unforeseen project costs. Replacement flexible connectors can easily add $5,000 to project costs and could take several weeks to obtain and delay installation. Sources for flexible connectors are limited and can also be difficult to locate. Most transformer manufactures will supply new flexible connectors at nominal costs when requested with the replacement transformer, if they are provided adequate detail to properly engineer.

There may be occasions when the existing transformer being replaced had no need for a fan rating or provisions for a fan cooling package. In the eventuality the replacement transformer is being specified or requested with a fan rating, consideration should be given to the issue of control power. It is common, for secondary equipment to be furnished with control power transformers intended to supply power for fan operation and other requirements. Typically a single ended unit substation would have one control power transformer, while a double ended unit substation would have two usually provided with a control power throw over scheme. Care should be taken to make sure that CPT's are present in the secondary equipment, and that they have sufficient capacity to provide the extra power for fan operation. If no control power transformers are present, either they will need to be installed, or the owner will need to provide a separate external control power source for the fans. The cost of installing control power transformers where none were previously required could be several thousand dollars, and may require significant downtime.

When undertaking a transformer retrofit where field measurements are to become the basis for a replacement figure #4 may prove useful. The following drawing in figure # 4 depicts the required field dimensions and information that should be gathered. While the drawing depicts a dry transformer, a liquid filled unit would require the same information.

Figure #4



It should be clear that when under taking a transformer retrofit, detailed planning is always a best practice. Purchasing just an electrical duplicate having similar dimensions as the original transformer is generally not the ideal solution having the least overall cost. Modifying this replacement transformer on site to fit can result in significant unforeseen costs and delays. It is suggested that early consideration be given to making sure that there is a suitable path through the owner's facility for both removal of the old transformer and delivery of the new transformer to its ultimate location.

Reference Material

"Rome Replacement Units (RRU)", 2004, Parts Super Center, Ed Mathis - Specialist, Bill Barron - Specialist, Jim Greer – Specialist
"ABB Drawing", ABB, 9/17/2013