Instrument Transformer Services (ITS)

Voltage / Potential Transformer Reclassification

CONTENTS

Purpose of this document

This document explains the technology and application of Schneider Electric's Instrument Transformer Services (ITS) offering for VT/PT Reclassification. It includes an overview of the hardware and software used in the application, and an example of a typical field installation procedure.

Executive Summary

Schneider Electric along with its technology partners and Square D Services has developed a service solution that allows live, dynamic characterization and accuracy improvement of medium- and high-voltage voltage/potential transformers (VT/PTs). The system relies on a highly accurate optical voltage transducer (OVT) used as a portable reference for live-line deployments at substations rated up to 500 kV.

The OVT is fully rated for permanent installation at 500 kV, including an 1800 kV BIL (lightning impulse) rating. The light weight, full insulation rating, and non-intrusive nature of the optical system enable it to be connected live to the HV line, without imposing expensive and difficult to arrange outages that are typically required for connecting test equipment to HV systems. The OVT has been integrated into a trailer for easy transportation and connection to HV lines. The trailer is designed to transport the OVT in a horizontal position. A radio-controlled hydraulic system is used to lift the column to the vertical and then to raise it for connection to the HV substation bus. Taking advantage of the inherent linearity of optical systems, a single OVT is used for calibrating devices on the 145 kV, 245 kV and 550 kV networks. The turns ratio is changed through software to the appropriate value for each voltage class. For lower voltage class substations having lower physical clearances, the trailer is designed so that the NXVT can be connected to the HV line while tilted.

By comparing the measurements from the reference OVT with the existing VT/PT, the system can produce error correction parameters for the reclassification of the existing VT/PT. These error correction parameters are programmed into an advanced revenue meter, which then dynamically corrects and effectively reclassifies the accuracy rating of the existing VT/PT.

The ITS System

At the core of the VT/PT reclassification system is a highly accurate reference voltage sensor, known as the Optical Voltage Transducer (OVT), which is deployed using live-line methods on voltages up to 500 kV. The OVT is a standard commercially available 550 kV class optical VT (an example of such a device is the NXVT - 500 supplied by NxtPhase T&D Corporation). It uses a distributed electric field sensor design and is filled with dry nitrogen. No oil or SF6 gas is used in the device. Voltage sensors of essentially the same design have been in operation in the form of combined voltage and current transformers (NXVCT-500) since March 2003. The OVT system was tested to the requirements of IEC 60044-7, IEEE/ANSI C57.13, and CAN-CSA-M83. The nitrogen pressure inside the NXVT-500 column is one atmosphere above ambient. Considering the internal separation of HV electrode and ground inside the NXVT column, even total loss of pressure does not cause a safety concern during normal operation or switching. This was demonstrated by switching impulse withstand tests with complete loss of nitrogen pressure. The NXVT was successfully tested with 15 positive and 15 negative switching impulses at 530 kV peak (peak of line-to-ground voltage for a 500 kV system × 1.3 safety factor). The NXVT-500 exhibits excellent linearity (better than 0.1%) over a wide dynamic range. Consequently, a single NXVT-500 is calibrated with three different scale factors for use on 525 kV, 245 kV, and 145 kV class networks (see Table 1) After testing and qualification, the OVT was mounted on a trailer, built by Powertech Labs Inc., to make a portable optical VT calibration reference that can be connected to HV conductors without taking an outage. Figure 1 shows the portable OVT together with the trailer. The trailer is designed with radio-controlled hydraulics for tilting and lifting the OVT column to connect to the HV line. Spring-loaded extensions are also provided to adjust the effective reach of the structure.

Table I. NXVT-500 nameplate information.

Maximum system voltage	550 kV		
Basic impulse insulation level	1800 kV		
Wet switching impulse level	1250 kV		
One minute withstand voltage	800 kV		
Rated frequency	60 Hz		
Earthquake withstand (Horizontal/Vertical)	0.5/0.5 g		
Weight	650 kg		
Rated maximum thermal current	3000 A		
Rated voltage: Primary (L-G) kV	303.1 kV	138	80.5
Rated voltage factor, continuous	1.1	2.0	2.0
Voltage accuracy class (IEC)	0.2	0.2	0.2
VT ratio @ scale factor	4500:1 0.5000	2000:1 1.1250	1200:1 1.8750
Burden	5 kΩ		
Temperature range	50°C to +40°C		

Figure 1: Portable OVT reference using a 500 kV optical VT

In addition to the OVT itself, the system also contains the OVT electronics and a pair of wireless GPS time-synchronized voltage sensors which time stamp and wirelessly transmit single phase voltage and phase angle readings of the primary voltage as well as the secondary voltage of the VT/PT under test. One sensor, the Primary Sensor, is located on the portable trailer and the second, the Secondary Sensor, is located in the substation control room connected to the secondary of the test VT/PT. No wires or cables are required throughout the substation.

Software compares the time-synchronized data from the Primary Sensor to the respective phase data collected from the Secondary Sensor to calculate the appropriate ratio correction factors (RCF) and phase angle correction factors (PACF) for each primary voltage point tested. These correction parameters are then programmed into the advanced revenue meter. This revenue meter dynamically corrects for the ratio and phase angle errors of the VT/PT over the voltage range tested. This effectively reclassifies the VT/PT to be of revenue metering accuracy.

Figure 2 (below) illustrates a typical system installation in a high voltage substation. The OVT is installed using live-line methods on the high-side bus in parallel with the existing VT/PT under test. The Secondary Sensor is installed in parallel with the test VT/PT secondary circuit. GPS time synchronized voltage and phase angle data is wirelessly transmitted from both the primary and secondary sensors to a PC where the data is analyzed. The process is repeated for each of the three phases.

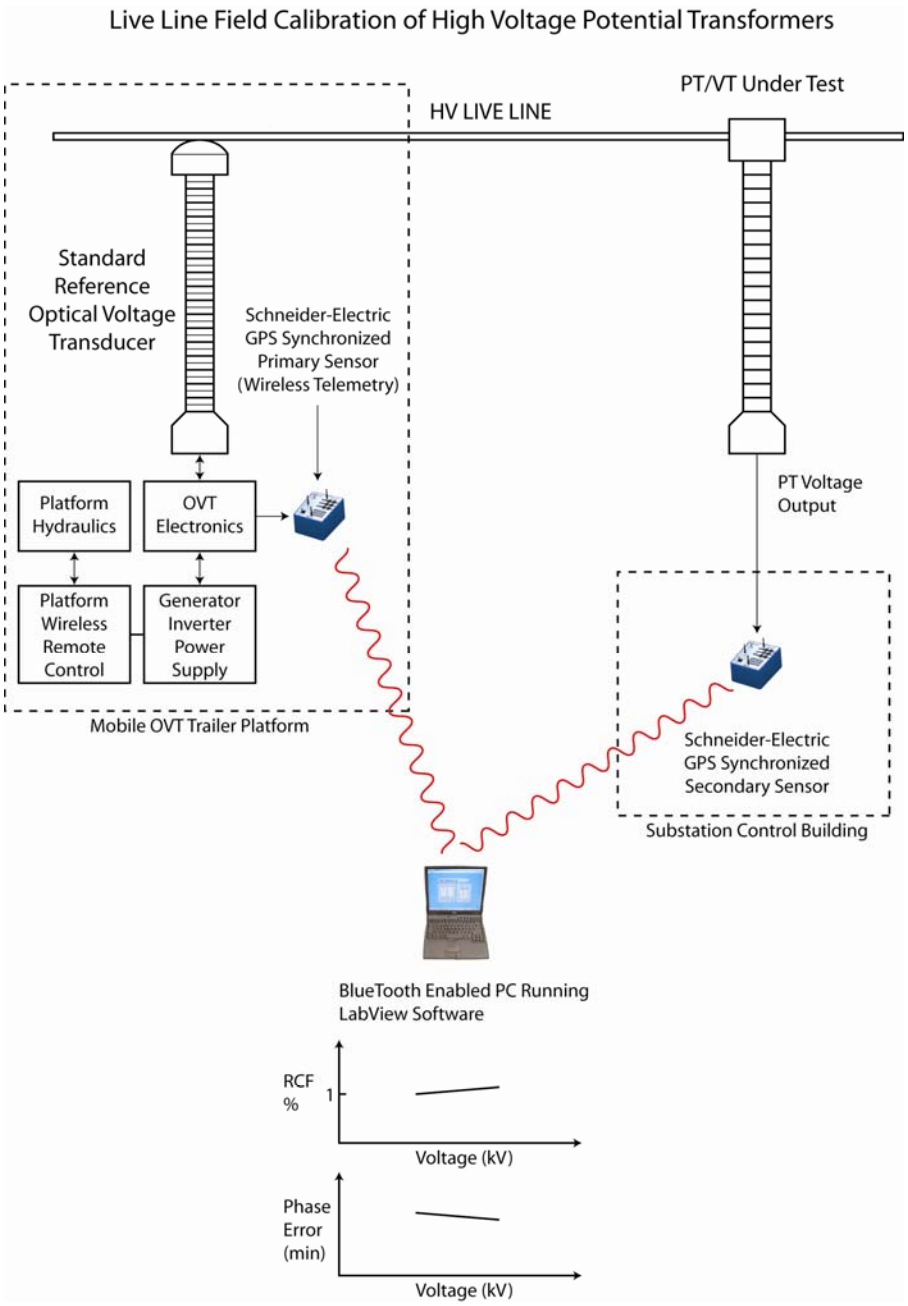

Figure 2: Typical Field Installation

Once all phases have been tested the system is left with only an advanced revenue meter connected to the secondary wiring of the existing VT/PT. The revenue meter, using the correction parameters, measures highly accurate voltage data and reports this back to the utility data collection and billing system. When this procedure is coupled with the Schneider Electric Current Transformer Reclassification (CTR) service the user is guaranteed to have the highest accuracy available in energy measurement for revenue metering purposes.

System Components

The OVT and Primary Sensor

The OVT is positioned and remotely raised until it is in contact with the primary bus (figure 3). The OVT is connected such that it will measure exactly the same primary voltage as the VT/PT under test. The OVT electronics feed measurement data directly to the Primary Sensor which has onboard recording of voltage magnitude and phase angle data. The unit can be configured via the Bluetooth link or serial port. During or when the test is complete, the data is sent to a computer via a Bluetooth wireless link. An onboard GPS receiver integral to the Primary Sensor provides time synchronization.

Features:

- Optical Voltage Transducer
- Highly Linear (better than 0.1%)
- Live-line installation
- Onboard GPS time synchronization
- Bluetooth wireless communications
- Electronics module for measuring RMS current magnitude and phase angle
- High voltage rating up to 500 kV

Fig 3. OVT Raised Into Contact With the Primary Bus

The Secondary Sensor

The Secondary Sensor (Figure 4) consists of a single unit for measuring individual phase voltage and angle. The unit is powered from a 120VAC receptacle and communicates via wireless Bluetooth. The unit connects into the test VT/PT secondary circuit either via jack-plugs in the existing test switch (preferable) or by hard wiring. An onboard GPS receiver provides time synchronization. As the unit is typically located indoors, an outdoor GPS antenna is required.

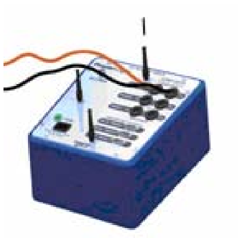

Fig 4. Secondary Sensor

Field Procedure

Summary

1. Using the mobility of the portable OVT position the OVT beneath the HV or EHV bus.
2. Ground the trailer.
3. Provide necessary power for the OVT electronics and Primary Sensor either by means of an external power source or via a portable generator.
4. Install a Secondary Sensor in the substation, connected to the secondary of the VT/PT under test.
5. Remotely control the position of the OVT until it is in contact with the HV or EHV phase under test.
6. Communicate wirelessly to the Primary and Secondary Sensors.
7. Gather GPS time synchronized data on a PC from the Primary Sensors and the Secondary Sensor. All natural voltage deviations will be recorded. The time required to gather data is a function of the specific nature of any voltage deviation present.
8. Reposition the equipment to test the other phases of the three phase power system (repeat steps 1-7)
9. Analyze data and calculate the accuracy error of the VT/PT under test.
10. Generate an accuracy report for each VT/PT under test and determine the needed correction factors.
11. Remove the equipment.
12. Move on to the next metering point and repeat the procedure.

List of Equipment Required

Part	**Details**	√
Laptop computer	Bluetooth capable with necessary software	
Portable OVT with Primary Sensor	Sensors	
Power cord or portable power source/supply	For powering the OVT electronics and Primary Sensor	
Secondary Sensor	Blue box	
	Power cord	
	Necessary connectors	
GPS repeater with power supply	For repeating GPS signal to inside of building	
GPS antenna and mount	Fix / support outside of control room	
Coax cable and connectors (BNC for repeater, TNC for antenna end)	For connection between GPS repeater and outside GPS antenna.	
1x Power Bar	Supply power to laptop, Secondary Sensor, GPS repeater.	
1x Extension cable	25 foot for power to laptop, Secondary	

	Sensor, GPS repeater..	
Standard tool kit	Screwdriver set, long nosed pliers, side cutters, small crescent wrench, wire strippers, multi-meter	
cable ties (12”)		
Spare parts for sensors	Boards, antennae, connectors etc TBD.	
Safety Equipment	Hardhats, safety shoes, eye protection, coveralls as required by customer site.	

Arrange for the Utility Company to provide:

Authorization to connect to VT/PT secondary	
Mounting for Secondary Sensor GPS antenna	
Hand Drill and assortment of bits (for antenna mounting if needed).	
Silicon sealer for hole to outside of relay house (if needed)	
2x Ladders (1 small, 1 tall): 1 to mount antenna on outside corner of control room; 1 to mount GPS repeater on inside of control room.	
Location for Secondary Sensor (probably on the floor next to metering panel)	
2x Shot gun hot sticks	
One set of drawings for station	
Hard Hats for those who need them	

VT Specifications

VT Manufacturer and Model:	Phase A	Phase B	Phase C
VT Ratio:			
System Voltage:			

OVT / Primary & Secondary Sensor Serial Numbers	
	OVT
	Primary
	Secondary

Typical Workflow

Site walk:

- Hold discussions with utility contacts to go over the pre-commissioning checklist.
- Review the appropriate substation drawings.
- Perform a site walk to meet contacts, determine proposed location of equipment and distances between locations. Take photos.
- Make appropriate arrangements if there is protection or metering equipment connected to the test VT/PT secondary.

Before commissioning:

- Check and calibrate (if necessary) the Primary and Secondary Sensors. Field calibration of the OVT is possible using a 20 kV (example), traceable reference PT and power source. Because of the proven linearity of the OVT calibration at a lower voltage can be used as justification for calibration at a higher voltage.

Installing the system:

- Complete the form part of this document with details for this deployment.
- Connect Secondary Sensor in the Control Room.
- Install GPS repeater if necessary. Otherwise, deploy GPS antenna with direct connection to Secondary Sensor.
- Connect the Secondary Sensor to the test VT/PT circuit
- Apply power to the Secondary Sensor from a 120VAC wall receptacle
- Using the laptop, verify communication to Secondary Sensor. Check GPS levels. Set proper ratio. In general verify readings/operation are as expected.
- Energize and Check communications to Primary Sensor
- Raise OVT to HV or EHV conductor
- Configure the Primary Sensors using the laptop. Verify communication to Primary Sensor. Check GPS levels. Set ratio. Generally verify that readings/operation are as expected.
- Check that the sensor pair is in-phase.
- Configure logging intervals on all sensors to desired rate
- Take photos of (try to capture panel/equipment labels for records):

Data collection and analysis

The system software is designed to perform three main functions

- Data collection
- Data analysis
- Report generation

The following procedures are performed by a certified Schneider Electric service engineer:

Steps:

1. Initiate the software to automatically collect data from the Primary Sensor (e.g. Phase A, Phase B, or Phase C) over the Bluetooth link
2. Initiate the software to automatically collect data from the Secondary Sensor (e.g. Phase A, Phase B, or Phase C) over the Bloothooth link.
3. System collects data over the necessary range of voltage or over a predetermined time interval.
4. Analyse the collected data, performing statistical analysis to calculate Ratio Correction Factor (RCF) and Phase Angle Correction Factor (PACF) for each VT/PT under test.
5. Generate a certified and traceable accuracy report for each VT/PT, based on the system calculated RCF and PACF error parameters.

Data Analysis

- Process the data using a custom Excel macro to provide ITC constants. The Excel macro application checks the sampled data and discards bad samples along with the synchronous sample form the other sensor.
- Examples of bad samples could include GPS not locked, once-off extreme RMS voltage values, etc.
- The macro then assigns the data into bins of like sample points.
- Linear regression is applied to the binned data to obtain 8 points on the VT characteristic for each of Ratio Correction Factor (RCF) and Angle Error.

Program meter with ITC constants

- Apply Instrument Transformer Correction data to the PowerLogic ION8000 series meter.
- PT/CT Correction can be configured in the ION8600 via ION software using ION Setup
- The PT/CT Correction Setup Assistant allows you to configure the *Instr Xformer* modules on the ION meters
- Open ION Setup and connect, in Basic Mode, to the desired meter
- Open the Revenue folder in the Setup Assistant and click PT/CT Correction
- For each desired tab, select the Correction Type, and simply input the Ratio Correction Test Data and the Phase Correction Test Data points

The Instrument Transformer Correction module is a core module; there is an ITC module for each current input (I1, I2, I3, I4) and for each voltage input to the meter (V1, V2, V3). Note that the correction affects only the 1 second values in the Power Meter module. No highspeed, harmonics, or waveform values are affected by the correction.

Manufacturing Standards

Schneider Electric's patented ION® technology is developed in world-class production and test facilities, along with an ISO-certified quality system, to ensure a wide range of the best products the market has to offer. We are the world's leading designer and manufacturer of advanced power monitoring devices and software certified to ISO 9000 Quality Assurance standards.

Schneider Electric certifies that our manufactured Power Monitoring and Control products meet published specifications and are calibrated and tested using equipment and standards traceable to the National Institute of Standards and Technology (**NIST**) in the US or the National Research Council of Canada (**NRC**).

As pioneers in the field of energy information and control we continue to define the leading edge. Our innovations include:

- First micro-processor based power meter
- First meter with remote communications capability
- First PC-based software for remote power monitoring
- First meter with on-board data, event, and fault recording
- First meter with programmable set-point capabilities
- First meter with object-oriented modularity and flexibility
- First revenue-approved meter with Ethernet support
- First meters with full Internet connectivity