CT RECLASSIFICATION AND VERIFICATION

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ABSTRACT

As a result of the liberalization of the energy market, formerly un-metered interchange points will require highly accurate metering for settlement billing. The prohibitive cost associated with upgrading existing instrument transformers to the required accuracy has forced the industry to explore using existing, lower-accuracy protection transformers as inputs to the energy meters. The true accuracy of these current transformers (CTs) is typically unknown and utilities and manufacturers are working together to determine the accuracy characteristics and the compensation necessary to use these transformers for settlement billing.

This paper will detail the various components within a new CT reclassification system that has been developed for this purpose. Focus is given specifically to the highly accurate reference current sensor that is at the core of the system. Details on its design and technology reveal the nature of its high accuracy and its ability to be deployed using live-line methods in a high voltage (HV) environment.

Test results and analysis of the data collected illustrate that the technology in each system component contributes to the overall increase in accuracy when a relay-class CT is reclassified. Through analysis of the test data, the characteristic performance of the individual CT is calculated and the corresponding error correction parameters are derived and programmed into an advanced energy meter.

Through the experiences gained at a 138kV utility substation, the system components and their respective technology were proven in a live, operational high voltage environment.

The research outlined in this paper illustrates the effectiveness of this new system to perform live, dynamic accuracy reclassification of existing relay-class CTs while operational in the field.

INTRODUCTION

The electric utility industry has experienced a lot of change recently due to pressures to open the competitive landscape in the electricity market. In regions where restructuring is occurring, some ISO and PUC organizations are mandating that local utilities meter previously un-metered locations on the power network with highly accurate revenue metering equipment. For example, in New York State and the province of Ontario, the independent system operators are mandating that their member utilities upgrade their metering infrastructure on wholesale and transmission inter-tie points. However, these ISO organizations are also aware of the significant financial burden this puts upon the utility. During deregulation of the Texas electricity market in 2000, ERCOT imposed new metering rules, forcing utilities to invest heavily in upgrading metering instrument transformers; one utility alone spent over $30 million to meet the requirement.

This has encouraged ISOs and utilities to explore the possibility of re-using existing relay-class current transformers (CT) for high accuracy revenue metering applications. The true accuracy of the existing CTs is typically unknown, and utilities and manufacturers are working together to understand the accuracy characteristics and determine if these CTs can be reused for revenue metering.

To address this need, a new CT reclassification system has been developed. The key component of the system is an innovative, highly accurate reference current sensor that can be easily deployed using live-line methods in a high voltage (HV) environment. This avoids any interruption to service. The system first analyzes the accuracy of an existing CT, calculating its characteristic performance. Corresponding error correction parameters are then derived and programmed into an advanced revenue meter, enabling dynamic accuracy reclassification of the existing CT while operational in the field. The new system has been proven in a live, operational high voltage environment at a 138 kV utility substation.

SYSTEM OVERVIEW

The reference current sensor, known as the primary sensor, can be deployed using live-line methods on voltages up to 765 kV. The sensor is based on a split-core active CT design that provides highly accurate measurement capabilities. This produces a system traceable to accuracy standards recognized by the National Institute of Standards and Technology in the USA and to directly related standards recognized by the National Research Council in Canada.

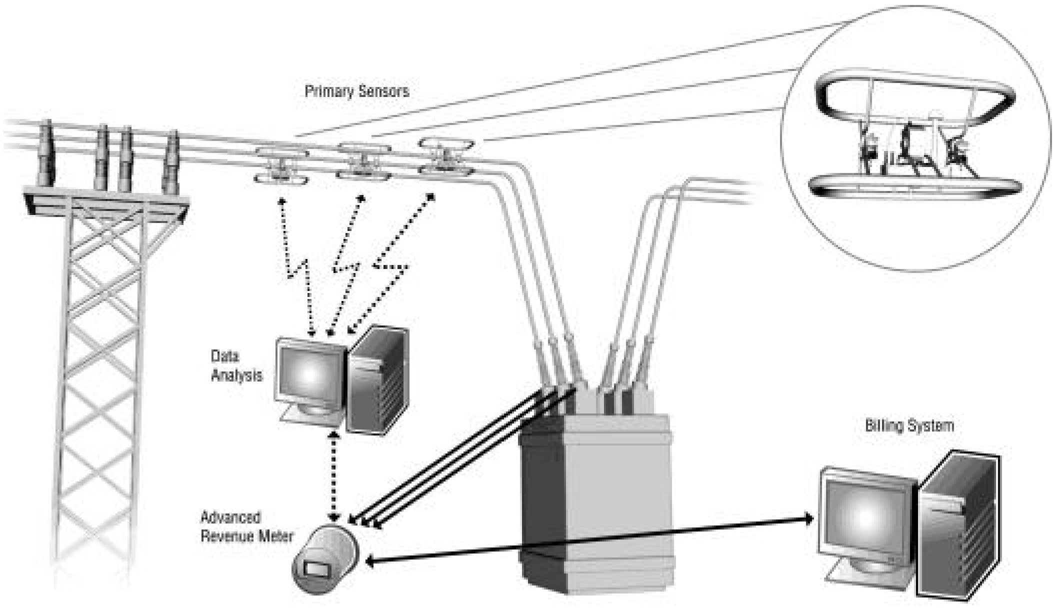

Figure 1 CT reclassification system with three primary sensors installed on the high voltage line and an advanced revenue meter connected to the secondary wiring of the existing relay-class CTs under test.

In a typical installation, three primary sensors are installed on the high-side bus in an HV substation in series with the circuit breaker containing the existing relay-class CTs under test (see Figure 1). The primary sensors each wirelessly stream data to a computer workstation in the nearby substation control building. The software simultaneously communicates to an advanced 3-phase meter, which is connected to the secondary wiring of the existing relay-class CT under test.

The three primary sensors and the advanced revenue meter are each equipped with a global positioning system (GPS) receiver that supports the accurate time-stamping and synchronization of all data sent to the computer for analysis. The software compares the data from three primary sensors to the respective 3-phase data collected from the meter and calculates the appropriate ratio correction factors (RCF) and phase angle correction factors (PACF) for each test point over the operating range of the relay-class CT under test. These correction parameters are then programmed into the advanced revenue meter which, in turn, provides dynamic correction for the ratio and phase angle errors of the relay-class CT over its operational range. This effectively reclassifies the CT to be of revenue metering accuracy.

The primary sensors and computer are then removed. The advanced revenue meter is left in place, connected to the secondary wiring of the existing relay-class CTs. The revenue meter, using the correction parameters, measures highly accurate energy data and reports this back to the utility data collection and billing system.

PRIMARY SENSOR TECHNOLOGY

The primary sensor acts as a reference standard against which the accuracy of the relay-class CT under test is compared. The innovative design of the primary sensor features a split-core active CT, an on-board GPS receiver, an electronics module for measuring RMS current magnitude and phase angle, wireless communications, and either battery power or a unique self-powering system.

The GPS units used on the primary sensors and advanced revenue meter produce time-stamping accurate to 100 ns. This enables the software to closely time-align data points from the sensors and the meter. It also ensures highly accurate phase angle measurements on the sensors and meter. Testing has shown the angular accuracy corresponds to +/- 5 minutes, or +/- 0.083 degrees.

An industrial version of Bluetooth wireless communications featuring a 2.5 GHz spread spectrum radio frequency is used. It was chosen based on its low power consumption, data encryption and highly directional 300 m range in an HV substation environment.

The sensor uses a CT to step down the high primary transmission line current to a level suitable for analog-to-digital conversion and subsequent digital signal processing.

The CT uses a split-core, actively compensated zero flux design. The split-core enables fast and easy installation by allowing the CT to be clamped over a live transmission line (see Figure 3). However, "splitting" a conventional toroidal CT typically results in degraded accuracy due to reduced effective permeability, increased leakage flux, and the difficulty in designing a mechanism that will properly align the mating core surfaces with repeatability. All of these factors will produce ratio and phase errors that prevent use in high accuracy, IEEE Std. C57.13 class 0.3 metering applications. Active compensation effectively removes

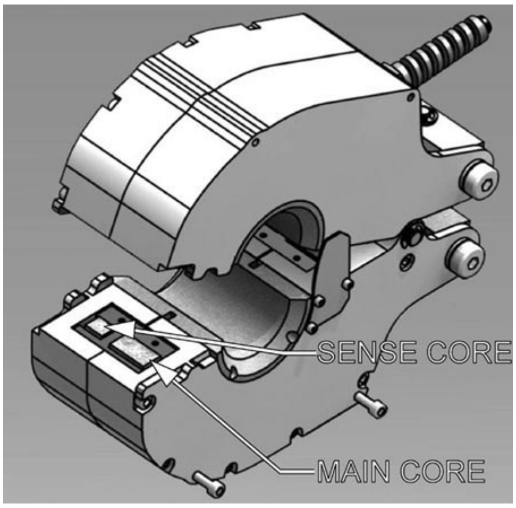

Figure 3 Open primary sensor CT

these sources of error and results in a split-core CT that has a higher ultimate accuracy. In fact, this design results in even higher accuracy over a wider dynamic current range than conventional "non-split" toroidal core CTs.

The CT employs a *main* and *sense* set of magnetic cores and windings. These are mounted within a high-tolerance mechanical structure that, when closed, precisely mates to form two independent toroidal magnetic circuits. Through special sense amplifier compensation circuitry, a zero flux condition is simulated which produces essentially lossless transformer operation. This, in turn, provides a near perfect ampere-turn balance between the transmission line and secondary winding of the main magnetic core, resulting in minimal ratio and phase error, thus maximizing the accuracy of the CT. Once compensated, the signal is digitally converted at 128 samples-per-cycle, time-stamped with GPS accuracy, and processed by the internal digital signal processor to provide RMS current and phase data. Overall, the primary sensor CT offers a 1000:5 ratio, handling primary transmission line currents of 1000 Amps RMS.

The primary sensor employs a unique electric field-based powering system that draws energy from the high voltage transmission line potential. It provides continuous operation at all transmission line current levels, including zero, thus allowing the primary sensor to operate over a very wide dynamic range. Long term reliability is ensured through simplicity of operation without the use of batteries, solar panels or other energy storage devices.

When positioned on a transmission line or substation bus, the sensor's galvanically-insulated tubular aluminum structure is designed to provide corona protection while also developing a finite body capacitance through which a small AC current can flow. On-board circuitry transforms this to a 2.5 W DC power supply that is more than sufficient to operate the measurement and communications components of the primary sensor.

LIVE LINE DEPLOYMENT

Weighing approximately 17 kg, the primary sensor can be installed and removed from an HV transmission line or bus using live-line techniques. A two-person crew can handle the installation easily, either from a bucket truck or from ground level.

The primary sensor is deployed using two shotgun hot sticks. Each hot stick is locked onto the eye ring of one of the two bus clamps on the primary sensor. The primary sensor is then lifted vertically toward the bus, maintaining proper clearances at all times. With the split-core CT open, the physical design of the primary sensor allows it to be guided easily into place, mounting it on the bus. Using the hot sticks, the two bus clamps are then screwed closed by turning the eye rings, securing the primary sensor to the bus. Once the primary sensor is secure on the bus, one hot stick holds the primary sensor steady while the other hot stick is used to screw the split-core CT mechanism closed.

The unit can be installed in less than 10 minutes. Line crews performing the installation must be properly trained in live-line work and understand the necessary safety issues when operating equipment in a live, HV substation environment.

LABORATORY AND FIELD TESTS

Laboratory testing of the CT reclassification system was thoroughly performed by Power Measurement at the company's Victoria, BC, facility and has also being performed at the utility laboratory of National Grid, USA Service Company in Syracuse, NY. The test qualified the overall end-to-end accuracy performance through in-circuit live current injection operation.

The test setup consisted of precision measurement references and a precision current source that duplicated an actual live field scenario. The industry-standard requirements for instrument transformers, under IEEE Std. C57.13-1993 Class 0.3, were used to bench-mark system performance.
Tests first confirmed that overall end-to-end performance for ratio correction factor (RCF) and phase angle correction factor (PACF) for the reclassification system fell well within the IEEE Std. C57.13-1993 limits.

The next step involved the reclassification of a conventional, large core 1000:5 bushing CT removed from an oil-filled circuit breaker. Performance of the 1000:5 bushing CT was characterized over a 20-150-20 A RMS current range and, as expected, the bushing CT did not comply with ANSI C57.13 -1993 Class 0.3 requirements. The RCF and PACF data was then programmed into the instrument transformer correction (ITC) module of an ION® 8500 advanced revenue meter. A precision current source was then applied to the bushing CT with a specific lagging power factor. The ION 8500 meter was used to measure the current, using the data in its ITC module to compensate for errors in the bushing CT. By comparing to a precision measurement reference, the results showed that overall system accuracy for the CT under test improved dramatically and met the IEEE Std. C57.13 class 0.3 requirements for revenue metering applications.

To further ensure success of the CT reclassification system in the field, extensive testing on instrument transformer correction was performed at the National Grid, USA Service Company engineering laboratories, in Syracuse, NY, USA. The research focuses on the variables affecting ratio and phase angle correction factors. Results showed that there are two key operational variables that have the most significant effect on RCF and PACF: percent primary current and the amount of the secondary burden on the CT under test. It was concluded that if the ranges of these and other potentially significant operational boundary conditions are well defined, monitored, and maintained, the complexity of the RCF and PACF correction algorithms can be minimized. This effectively maximizes the accuracy and reliability of the reclassified CT and metering system.

Live-line, high-voltage field tests were performed to further validate the accuracy and performance of the CT reclassification system. The first evaluation site was provided by BC Hydro and BC Transmission Company. Starting in February 2005, tests began in a substation with a 3-phase circuit breaker on a 138 kV line as the evaluation point. The breaker contained relay-class current transformers rated for a nominal current input of 800 A. The secondary wiring of the relay-class CTs are connected to a variety of protective relaying devices located in the substation building. The 138 kV line where the CTs under test are located experiences current flow in both directions. This line is connected to generation stations downstream. The generation operates part time; as a result, the current flow direction changes to accommodate the load change.
As part of the complete CT reclassification system, the ION 8500 advanced revenue meter was located in the substation building and connected to the secondary wiring of the three relay-class CTs under test. Three primary sensors were installed on the 138 kV high voltage line in close proximity to the breaker and in series with the relay-class CTs within the breaker. A data collection computer located in the substation building collected the measurement data from the advanced revenue meter and the three primary sensors.

The test provided proof of end-to-end system operation. This included validating the reliable operation of the sensors' wireless Bluetooth communications in the HV substation environment and the successful operation of the primary sensors' self-powering mechanism. Crews from BC Hydro also confirmed that the three primary sensors were easy to install using live-line methods and could be installed in less than 30 minutes.

Further evaluation sites are under way with National Grid, USA Service Company in Utica, NY, USA and Georgia Power in Columbus, GA, USA. Thus far the compelling data supports that reclassification of existing relay-class CTs can be performed live, in-situ, during full operation of the CT. The resulting reclassification of the CT ensures improved accuracy to meet the necessary IEEE Std. C57.13 Class 0.3 requirements for revenue metering CTs, allowing the re-use of existing infrastructure and avoiding the high cost of CT upgrade and replacement.

AUTHOR BIOGRAPHIES

Brian Kingham received his Bachelor degree in Electrical Engineering from the University of Victoria in 1995. He has held a number of positions in Research & Development and Operations before moving to his current role as Utility Market Manager. In this role Kingham defines the company's marketing and product strategy for the utility market.

Colin Gunn received his Bachelor of Electrical Engineering from the University of Victoria in 1989 with specialization in communications technology. He joined Schneider Electric in 1997 where his research interests have focused on AC energy metrology with emphasis on current comparator technology and high voltage field analysis. He holds six US patents.