Overview

The Model 1133A Power Sentinel™ offers accuracy in power measurement of 0.025%. Existing CTs provide accuracy of a few tenths of one percent. How then can the Model 1133A actually provide accuracy of 0.025% in the field?

The answer is calibration of the CTs. By comparing each CT to an accurate reference CT, traceable to national standards (for example, NIST in the USA), the errors of the test CT can be determined at several currents and the correction factors entered into a table in the Model 1133A. The Model 1133A uses these correction factors, interpolating between them based on the measured current, to correct measured power (and current) to the actual values, in real time, within the instrument's stated accuracy.

Calibration Process

To calibrate the CTs requires three things: first, a calibrated reference CT; second, a source of high current; and third, some means of comparison. Each of these will be addressed below.

Calibrated Reference CT

Arbiter Systems plans to develop an accurate, multi-ratio reference CT suitable for these calibrations, and suitable for calibration by national standards laboratories at an accuracy which exceeds 0.01% (the present limit of traceability at NIST). This CT will have ratios of 1000:5, 800:5, 750:5, and 600:5. It will operate accurately at currents from 0 to 200% of rating. Using a two-stage, amplifier-aided design, this CT should be fundamentally capable of accuracy better than 10 ppm (0.001%).

By using a multi-turn primary through the center of the reference CT, current ratios of (1000/N):5, (800/N):5, (750/N):5, and (600/N):5 can be provided as well (with N equal to the number of turns). By using a multi-turn primary on the CT under test, ratios of (1000*M):5, (800*M):5, and so on can also be provided. And finally, by using both N turns through the reference CT and M turns through the CT under test, ratios of (1000*M/N):5, (800*M/N):5, and so on can be provided. This allows a wide range of test CT ratios to be calibrated with a single accurate reference artifact.

Excitation Current Source

To provide the high currents required to perform the calibration, we also plan to provide an excitation current source. This will work on the principle of a "CT in reverse," that is, a 'donut' having a multi-turn primary excited at a reasonable current level (5 to 10 amps maximum). This device will allow a heavy-gauge winding to be placed through its center, exciting it at the high currents required (up to 2000 ampere-turns).

While it is possible, and perhaps even desirable on some accounts, to provide a regulated, solid-state source to drive the excitation coil, this would be very expensive and heavy considering the powers involved (up to 1000 VA). Due to the accurate ratiometric measurement technique to be proposed in the next section, it is not necessary to have the excitation current be particularly accurate or even stable. Therefore, we can use a much simpler, 'brute-force' design based on a multi-tap autotransformer and Variac to set the current. The design contemplated will offer settings for input voltage range (100, 120, 200, 220 and 240 Vrms) and output range (100, 50, 20, 10 and 5% of full-scale), and continuous adjustment from zero to the selected output range. The device would be powered from the customer's ac main power.

Comparison Technique

The most direct method of comparison involves making a measurement using the reference CT, then using the unknown, and then calculating the ratio correction factor and phase angle from the data (figure 1). This has the drawbacks that the current source and measurement device must be substantially more accurate and stable than the desired measurement result, typically by a factor of 4 or 5. If this were possible, it would greatly increase the cost and size of the equipment.

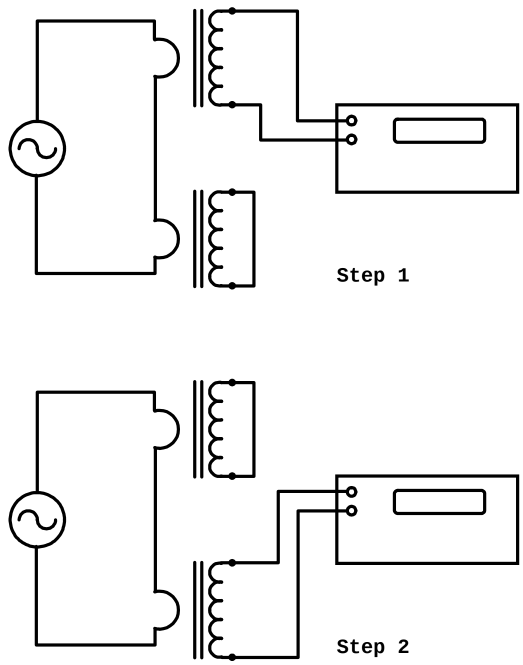

Figure 1

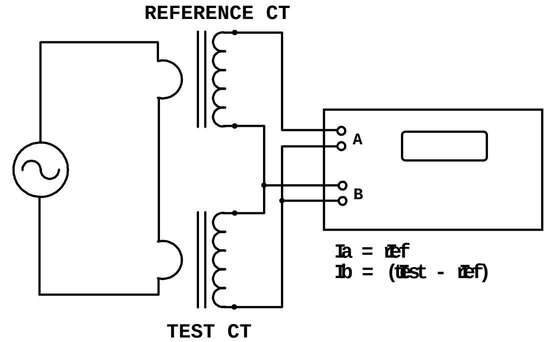

Figure 2

A better technique is called nulling (figure 2). In this method, the outputs of the two CTs, reference and test, are subtracted electrically by using superposition (Kirchhoff's law), and the difference (error) measured directly. This subtraction is exact, and introduces no error. Using a second channel of the same measuring instrument, the actual secondary current can also be measured, and the ratio correction factor and phase angle are then determined mathematically. Best of all, if the measuring instrument can make the two measurements simultaneously, then effects of source variations cancel out. Furthermore, since the quantity being measured is a small error, equal to at most about 1% of the secondary current, the accuracy required of the measuring instrument can be relaxed as well.

The ideal instrument to make this comparison is the Arbiter Systems Model 931A Power System Analyzer™. This instrument samples both of its selected input channels simultaneously, meeting the requirement stated above. Best of all, measuring the error current with 0.05% accuracy, the Model 931A is capable of making this comparison at a level of 5 ppm of the secondary current (0.05% of 1%). This standards-lab performance can readily be achieved in the field using rugged, portable equipment designed for field use, operated by service technicians with little or no training in metrology techniques.

Accessories

This setup will be provided with the necessary accessories to perform the required calibrations. The cable carrying the high primary current will be AWG 4/0 welding cable, capable of up to 500 amps current. For applications where the cable can be run through the center of the test CT, a single long length (about 15m or 50 ft.) of cable will be provided, allowing for multi-turn setups. To perform a calibration of, for example, a 1000:5 CT at currents up to 2000 amperes, four turns are required through each of the excitation CT, the test CT, and the reference CT.

For applications where the current must be provided to a bar running through the test CT, four shorter (3m or 10 ft.) cables will also be provided. The lugged ends of all of the cables are connected to the primary of the test CT. This would form a single-turn loop, with each cable carrying 500 of the 2000 amperes of current.

Software will be provided to automate the data gathering and reduction process, using a serial connection to the Model 931A and prompting the operator to perform the proper hookup and settings of the other equipment. The data could later be printed out, and it can be stored in a data file suitable for use when configuring the Model 1133A, eliminating a manual step where errors could enter into the process.

Hardware required to connect the lugged ends of the cables together, completing the high-current loop, and tools to tighten the hardware to specification, will also be a part of the kit.

Conclusion

Taking advantage of the full accuracy of the Model 1133A Power Sentinel™ requires calibration of the user's CTs. This paper presents a method to perform these calibrations. Using two new products to be developed by Arbiter Systems, a high-accuracy reference CT and an excitation current source, and an Arbiter Model 931A Power System Analyzer™, calibrations will be done at primary currents up to 2000 amperes (higher under some conditions) with a transfer accuracy of 5 ppm and an overall traceable accuracy of 0.01% or better.