AN12827

Single Point Meter Calibration

Rev. 0 — 23 April 2020 Application Note

Contents

1 Introduction

Modern electronic power meters are designed to achieve energy measurement accuracy of ±1.0 % (or even better) in the current range from 0.1*base current (Ib) to maximum current (Imax). Normally voltage, current, powers, phase angle, and frequency are regarded as measurement values or non-billing quantities, while active energy and reactive energy are regarded as metering values or billing quantities. An electronic power meter is consists of hardware and software. Hardware components have tolerance; therefore, its absolute value varies on each board. To achieve accuracy, calibrating of each electronic power meter is must and the calibration is done using a high-precision calibration equipment. Such calibration equipment comprised of an accurate reference meter and power source.

The active and reactive energy consumption is accumulated in respective energy registers/variables. The values of energy registers/variables are either communicated or made accessible to utilities for billing purposes. Electronic power meter energies (Apparent(S), Active (P) and Reactive (Q)) can be imported and exported based on the voltage, current direction, and phase angle. Figure 1 shows electronic power meter operation in all four quadrants.

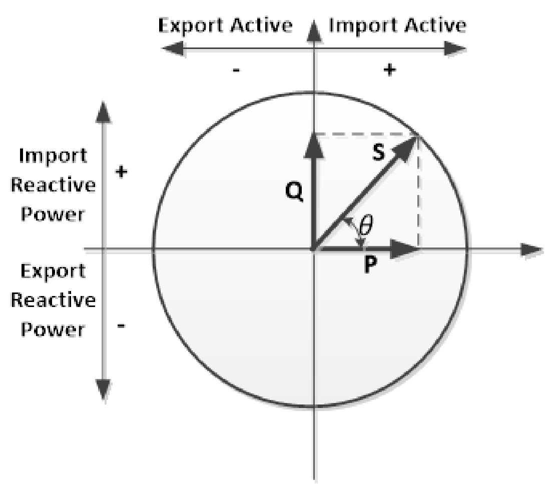

Figure 1. Power meter operation in energy quadrants

The electronic power meter measures the active energy and generates pulses on the calibration LED. And each pulse is equals to the active energy amount in kWh/meter-constant consumed by the load. Hence, meter-constant is numbers of pulses per kWh consumed. The error is calculated by comparing pulse of reference meter by pulse generated by electronic power meter. This error is used to determine the accuracy of the electronic power meter.

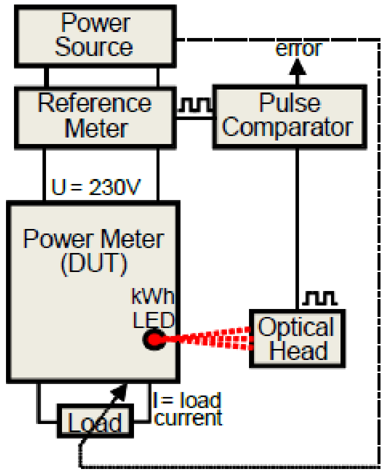

Figure 2. Production calibration and testing equipment setup

2 Error calculation

The purpose of the electronic power meter is to register the active and reactive energy consumption precisely. Hence it is necessary to calibrate the electronic power meter using a calibration equipment that comprised of an accurate reference meter and inaccurate (or even unregulated) power source. Such calibration systems are capable of measuring the energy errors with high accuracy. But we cannot rely on the accuracy of the phase voltage and phase current waveforms amplitudes generated by the power source. In such cases, calibration of the electronic power meter is based on energy errors computed by the pulse comparator.

The pulse comparator computes an energy error as a difference between the energy consumption measured by the electronic power meter and the reference energy consumption measured by the reference power meter.

The energy error (in percent) is computed as follows:

Equation 1:

$\text{Error} = ((T_{mtr} - T_{ref})/T_{ref})*100$

Where T_{mtr} is the period of the electronic power meter pulse output, and T_{ref} is the period of the reference power meter pulse output.

The accuracy of energy calculation is based on two factors:

1. Pulse generation resolution.
2. Accuracy of the electronic power meter to calculate the energy value and generating pulses accordingly.

During the calibration process, we calibrate phase angle, voltage, and both phase current and neutral current along with calibration of energy calculated from measured parameters. The calibration of energy must make sure that it compensates the error introduced by software calculation and hardware components..

3 Calibration technique

Calibration of the electronic power meter is done in order to compensate for variations introduced by meter hardware components. The calibration technique is based on measuring and comparing the reference values. The energy errors are computed as a difference in the pulse output rate of the electronic power meter under calibration and reference power meters. The goal of the electronic power meter calibration is to calculate suitable voltage gain(coefficient), current gain(coefficient), power gain(coefficient), frequency coefficient, and phase angle coefficients, and to apply them after calibration. Calibration of the electronic power meter can be done in auto calibration method. In Auto Calibration user feeds a known voltage, current, phase angle and frequency from highly accurate reference source to electronic power meter and there is no manual interference during calibration process. When electronic power meter gets calibration commands, meter software calculates all the required parameters such as voltage, current, power, frequency, and phase angle and compare it with reference source value and calculate the respective coefficients and stores them in Non-volatile (NV) memory. The high-level block diagram of calibration software input and output is shown in Figure 3. Calibration process is time consuming process and therefore it effects the electronic power meter production rate.

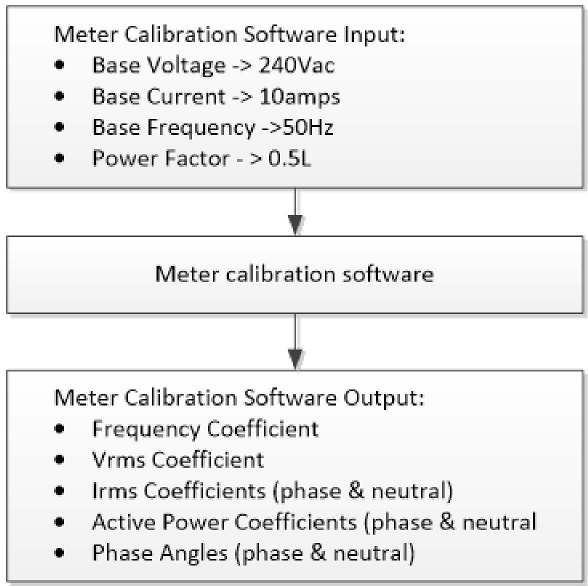

Figure 3. Calibration meter software input and output

In general electronic power meter calibration done on two points, one at keeping power factor (PF) as 1.0, and second at PF as 0.5lag (L) and keep all other parameters voltage, current and frequency same. To optimize calibration time, we choose single point calibration for class 1.0 meters. Question may ask why single point calibration would be good enough at PF 0.5 L. The answer is PF 0.5 L is the peak of input cycle in terms of power calculation with respect to any other phase angle point error. Hence, any error in phase angle calculation/measurement produces maximum error in power calculation. if electronic power meter is calibrated at PF 0.5 L then it ensures less error power/energy calculation at any other phase angle points. Hence, single point at PF 0.5 L calibration is sufficient to meet class 1.0 electronic power meter accuracy requirement.

3.1 Single point calibration

Energy calculation in electronic power meter is depends on input measured parameters such as voltage, current, power factor and frequency. Calibration software in the electronic power meter calculate the multiplying factor known as calibration coefficients. Once electronic power meter software receives calibration command, it will first initialize the calibration point as defined below:

- Input voltage rms = 240 V
- Input current rms = 10 A
- Power Factor = 0.5Lag PF
- Frequency = 50 Hz

The reference power source output should first configure to provide output voltage, current, power factor and frequency as above before giving calibration command to electronic power meter. After initialization, accumulation of input parameters for six cycle at each stage and then calculation of calibration co-efficient happens. Calibration process goes to various stages in software to calculate the final calibration coefficients for each measured and calculated quantity.

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The calibration steps are:

- CalibSetup: Software sets up its calibration points
- CalibAngleAccumulate: Software accumulates parameters for six metering cycles
- CalibAngleApply: Calculate the coefficients for phase angle based on accumulated parameters.
- CalibAccumulate: Software accumulates all its sensing and calculated parameters for six metering cycles
- CalibApply: Calculate coefficients of all the measured and sensing parameter based on the accumulated parameters
- CalibMemoryWrite: Calibration coefficients are written on NV memory as well as external memory

3.1.1 Calibration software flow

Calibration start command is given through communication port. Once software received calibration start command it first sets Calibration progress flag and assigned calibration state as calibration progress (CalibState = CALIBSTATE_PROGRESS). Figure 4 is software flow diagram of calibration process, each accumulation is done for six cycles:

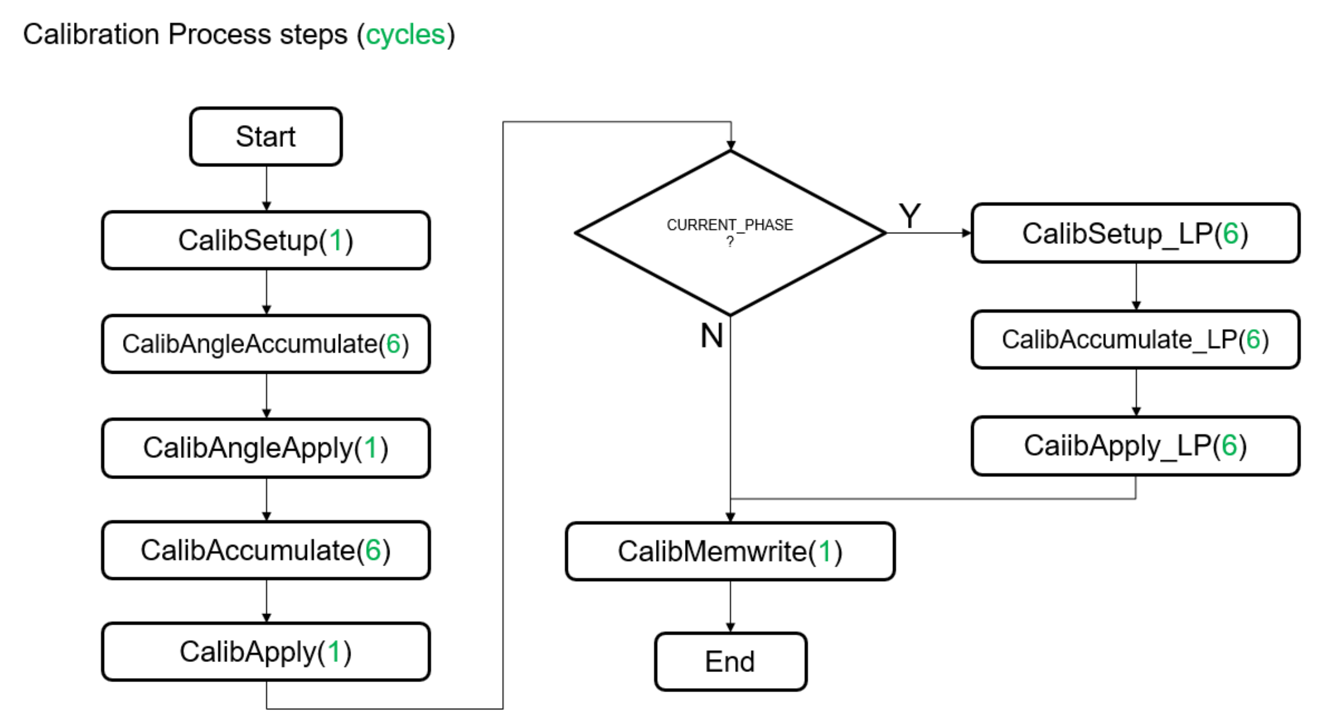

Figure 4. Software flow diagram of calibration process

Phase error and phase angle coefficient calculation has been elaborated in Figure 5.

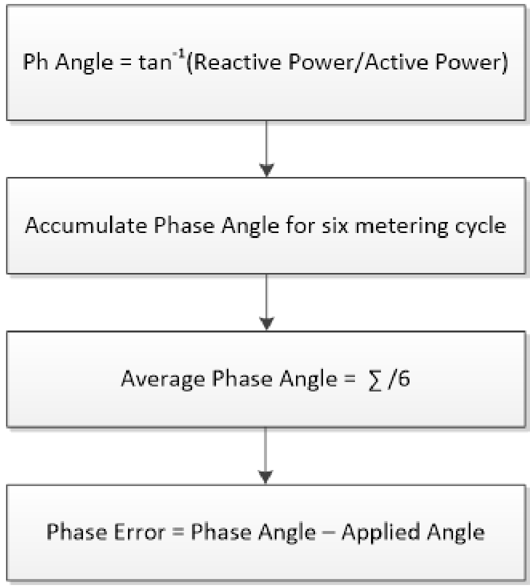

Figure 5. Phase angle calibration coefficient calculation

Ratio (coefficient) calculation of input voltage, phase current and neutral current is elaborated in Figure 6.

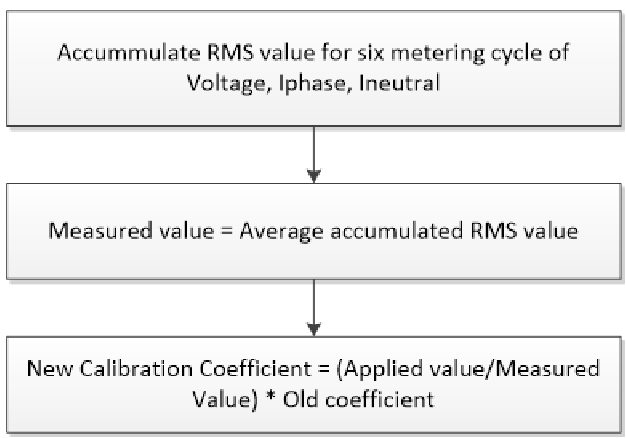

Figure 6. Calibration coefficient calculation

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The last step of calibration process is the store the calibration coefficient into flash as well as to external memory, so that after every power on reset it can fetch the calibration coefficients for calculations of billing and non-billing meter quantity. After storing all the calibration coefficient, calibration complete flag is sets and changes the calibration state to calibration complete (CalibState = CALIBSTATE_COMPLETE). After calibration process completes, all the billing and non-billing meter quantity re calculated with new calibration coefficients.

4 Summary

This application note describes the electronic power meter calibration approach suitable for using with test equipment which can provide reference voltage and current with defined phase angle with. The described single point calibration technique is based on measuring energy errors of the electronic power meter at single calibration point: Power Factor (PF) = 0.5 L.

The equations for calculating the calibration coefficients from measured energy errors re determined, and their accuracy is verified by test bench test. The NXP Kinetis-M power meter reference design is installed on the metering test bench, calibrated using single point calibration technique, and the accuracy of the reference design is verified after the calibration. The accuracy energies at all power factors are -0.16/+0.13% in the voltage, current, frequency, and PF range.

The repeatability of the single point calibration technique is also verified with different hardware of various customer electronic power meters. For more detail of the reference design, see AN12837.

The described single point calibration technique is suitable for use on production lines. It provides an excellent accuracy and repeatability. Single point calibration saves calibration time as it has performed only at single point setting of test bench, therefore it improves production run rate.

5 Revision history

Table 1. Revision history

	Revision history	
Revision number	**Date**	**Substantive changes**
0	04/2020	Initial release

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