Progress Report: Integral Metering and Reporting Capabilities of Networked Lighting Controls

Networked lighting control (NLC) systems have proven they can successfully reduce demand and save energy in real-world applications through a combination of basic and advanced control strategies. However, the potential of NLCs' integral metering and reporting capabilities has not been fully realized. This is, in part, due to the variety of metering and reporting approaches used by today's NLCs.

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To address this issue, the California Lighting Technology Center at UC Davis partnered with RMS Energy Consulting, LLC, and Southern California Edison to assess the accuracy of today's commercially available NLCs' integral energy meters and compare their performance to current utility requirements, such as revenue-grade metering.

This is the second phase of an ongoing effort, where the initial phase included the development of a test procedure for evaluating the integral metering and reporting capabilities of NLCs as well as the associated results for three NLC systems. The initial NLCs tested used varying approaches to energy metering, including correlated, apparent and true power. A key outcome from Phase 1 was that the "true power" approach was the most accurate and should be explored further to understand if it was appropriate for use in "pay-for-performance" incentive programs. See *LD+A* November 2015 "Research" for results from the initial project.

During the second phase of this effort, the preliminary test procedure was refined to address new standards published since Phase 1 and updated market assessments. Three representative NLC systems and one revenue-grade system were evaluated using this updated test procedure. As recommended in Phase 1, all four tested systems utilized the "true power" approach for energy metering.

The test procedure to evaluate the energy metering accuracy, consistency, and reliability of NLCs is based on the ANSI C12.1-2014 and C12.20-2015 standards and allows researchers to compare the onboard energy metering performance to that of a reference power analyzer. Compliance with ANSI standards is voluntary for manufacturers; however, these standards are commonly used by North American utilities as the basis for their revenue metering requirements. Both ANSI standards specify requirements for meters while experiencing variations in load, power factor, voltage, frequency and other conditions that may affect the meter's accuracy. Additionally, ANSI C12.20-2015 includes test methods for meter accuracy when measuring loads with harmonic waveforms.

Three pieces of laboratory equipment were specified for testing: 1) a precision alternating-current (AC) power supply, 2) a programmable AC load and 3) a reference power analyzer.

Multiple load controllers for each NLC system were tested while controlling four representative lighting waveforms simulated by the programmable AC load. To determine these waveforms, CLTC researchers considered 44 available lighting products and identified archetypal groups. The lighting waveforms that posed the greatest challenge for the power meters' current transducers and data acquisition components were selected for testing to quantify performance when dealing with complex real-world lighting loads.

To understand the performance of the onboard metering and reporting capabilities for "dimmed" lighting loads, the current levels for each waveform were tested at 0.1 A and increased incrementally to either 1) 90% of the device-under-test's (DUT) rating threshold or 2) the maximum output of the power supply at 14.5 A.

Results from the NLC testing showed that integral metering can reliably deliver high accuracy in multiple test conditions and could hypothetically replace revenue-grade metering in some situations. However, no commercially available system today meets the 2% accuracy requirement for revenue-grade labeled devices across all test conditions. Additionally, issues with sample consistency for the same NLC product were noted, as identical model load controllers were unable to maintain agreement in various test scenarios.

Of the three NLC systems tested, System 1 was the most accurate, with an average error of 2.3% compared to the reference power analyzer. For the same subset of tests, System 2 resulted in 8.6% average error compared to the reference power analyzer, mostly due to logging errors in the high amperage tests. System 3 did not meet the manufacturer's

	System 1	System 2	System 3	Revenue-grade System
Worst-case Performance Average Percent Error for 0.1 A Test	20.63%	9.27%	897.96%	6.88%
Best-case Performance Average Percent Error for 1 A Test	2.83%	0.77%	159.43%	0.43%
Average Performance Average Percent Error for Tests across dimming range of typical lighting load waveforms other than 0.1 A Test	2.31%	8.56%	129.08%	Not Applicable

Table 1. Summary of average percent error for all load types for worst-case performance scenario, best-case performance scenario, and average test results for all NLC test scenarios above 0.1 A.

CLTC R&D engineer preparing DUT for testing.

data. System 2 was the most challenging system to record and export energy use information, as it was necessary to include a building management system that required extensive code development. System 3 offered a simple data recording and export process; however, the system required a SQL database on a dedicated computer which can be cumbersome for end users to maintain and navigate.

While all tested NLC systems utilized the "true power" metering approach that independently measures current and voltage, the results show system design requirements to ensure accuracy are highly complex as all three systems performed differently.

Overall, the installation process for the NLCs with integral metering are more straightforward as compared to a separate revenue-grade system combined with a lighting controller. The NLC systems offered more control and data display features than the revenue-grade system and were easier to integrate with BMS as compared to the revenue-grade system. With respect to cost, buying and installing an NLC load controller with an integral meter is significantly less expensive than purchasing and installing a revenue-grade system. The incremental costs associated with upgrading an NLC load controller to include an integral

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rated accuracy in 95% of the test scenarios which resulted in an average error of 129%.

In addition to the average performance analysis, test conditions where the three NLC systems performed their best and worst were chosen for comparison with the revenue-grade system. The best-case performance scenarios were the 1 A tests; and the worst-case performance scenarios were the 0.1 A tests. Under the best-case scenario, System 1 had an average error of 2.8%, System 2 had an average error of 0.8%, System 3 had an average error of 159%, and the revenue-grade system had an average error of 0.4%. While lighting loads at 0.1 A do exist, especially when dimmed, most readily available revenue-grade meters do not support the resolution required to accurately report energy use of loads at this amperage operating for short periods of time.

With respect to NLC's reporting capabilities, System 1 was the most user-friendly system to record and export energy use

Defining 'Power'

Correlated Power: NLCs that use "correlated power" record the control signal (e.g., 0-10-V or DALI) for each luminaire in the network. The signal is correlated to the associated power level of each monitored load based on a dimming vs. power curve, typically provided by the luminaire manufacturer. The correlated power method reports assumed energy use instead of actual energy use.

Apparent Power: "Apparent power" occurs when the current draw of the device is measured, and the voltage is assumed. This method does not account for any phase difference between the current and voltage waveforms, distortion to the voltage waveform, or deviation of the expected voltage from the assumed value, such as 120 Vrms.

True Power: "True power" occurs when both voltage and current are measured simultaneously. Best practice includes sufficient temporal resolution to capture the time-varying waveform. Each power measurement requires a voltage transducer, a current transducer, and two data acquisition channels. The necessary rate of acquisition is based on load type and is a function of the rate of change of the voltage and current signals, also known as the slew rate. Average power obtained using true power measurements is given by Equation 1.

$$P_{avg}=\frac{1}{t_2-t_1}\int_{t_1}^{t_2} V(t)I(t)dt$$

where $V(t)$ = instantaneous voltage at time t

$I(t)$ = instantaneous current at time t

Equation 1. True Power monitoring function for calculating average energy use with time varying voltage and current.

meter was calculated to be 57-82% less expensive than purchasing a revenue-grade system.

While it is possible to design "pay-for-performance" measures built on the premise of NLC-provided energy data, no system tested can provide equivalent accuracy, consistency or reliability as compared to revenue-grade systems. However, the detailed results indicate the technology and approaches required do exist today and with simple modifications to software and/or meter selection NLCs could meet the ANSI C12.1 accuracy requirement.

In parallel to the testing reported in this article, CLTC is also evaluating the accuracy and reliability of NLC systems with plug load controllers when controlling miscellaneous electric loads (MELs). MEL load type selection focused on commercial building applications, including typical office equipment (e.g., computers, printers, copiers), task lighting, consumer electronics and kitchen appliances. As the NLC market that includes integral metering matures, utilities and policymakers will be positioned to take advantage of this energy-use data for incentive programs and outcome-based code opportunities. ◎

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