Can Connected Lighting Provide Grid Services *and* Effective Illumination?

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Among the many ways LED lighting is changing the definition of what lighting can do and be is by enabling the development of connected lighting systems (CLS). LED technology facilitates the integration of intelligence, network interfaces, and sensors into lighting devices, which can result in reduced energy consumption and improved lighting performance. But CLS also has the potential to provide a broad range of electric grid services, particularly those that rely on a fast load modulation (such as frequency regulation)—for which many other building end uses (e.g., heating, ventilating, and air conditioning) are not well suited. While that potential has yet to be proven or quantified, a team of researchers at the U.S. Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) is working to do just that. Through modeling and simulation, followed by lab and field testing, PNNL is investigating the ability of connected lighting systems to deliver grid services over a wide range of building and grid operating conditions, in ways that meet lighting-user needs and expectations.

Grid services support the generation, transmission, and distribution of electricity from the utility to the consumer and provide value through avoided electricity costs (such as reduced cost for generation or delivery of electricity)—thus saving energy. To date, grid services are generally provided by the supply side (e.g., integrated utilities, grid operators, and generators), but this can result in generators that remain idle for long periods of time, as well as (in the case of fossil-fuel generators) environmental concerns. Meanwhile, there's mounting evidence that providing grid services from the demand side (e.g., from commercial buildings) is an effective alternative with huge potential.

In 2018, the residential and commercial sectors accounted for about 39 percent of total U.S. energy consumption. More than 70 percent of total U.S. electricity use is approximately one-half to one-third the levelized cost of generated electricity, because it alleviates transmission and distribution congestion rather than exacerbating it. It also often leads to deferred or avoided infrastructure build-out and upgrades. Beyond using less total energy, an energy-efficient building benefits the grid by maintaining low energy use even during typical periods of high demand.

To help pave the way for tapping the potential of buildings providing grid services from the demand side, the PNNL investigations hope to find answers to key questions: How can we quantify the potential for CLS to provide electrical grid services? Can CLS deliver substantial grid services under a wide range of building and electrical grid operating conditions in ways that balance stakeholder needs and expectations? How might CLS manufacturers develop more effective, grid-responsive CLS?

CLS is capable of both rapidly reducing and increasing their electrical demand, and CLS power draw can be quickly modulated by varying light output, spectrum, and distribution, thereby providing grid services at increments of anywhere from hours (e.g., for energy services) to seconds or even less (e.g., for frequency regulation and response). What's more, CLS can monitor energy use and space conditions that affect occupant satisfaction, and can share historical and projected data for coordination and optimization with other building equipment. However, the ability of CLS to deliver grid services while also delivering sufficient lighting service and occupant satisfaction has not yet been proven or quantified—which is where the DOE studies come in.

PNNL has developed a model for CLS using a set of parameters to represent key operation behaviors and constraints intended to maintain occupant satisfaction, including lighting power flexibility (maximum, nominal, minimum) over the course of the day for each of the DOE Commercial Prototype Buildings, delay in initiating response to a grid signal, and maximum lighting-load change rate. The model has thus far been integrated into a simulation platform that allows for the exploration of how CLS, acting alone, might respond to price signals from the grid. A lighting power demand curve that relates lighting load to electricity price was developed, and a transactive control method was simulated to quantify the amount of the grid service that might be obtained, given a specific price trajectory and demand curve.

PNNL is currently running simulations that explore the impact of response delay, change rate, and maximum lighting reduction on lighting demand reduction, energy consumption, and energy cost for a variety of building types—initially focused on office buildings of various sizes. The initial results show that the simulation platform is functioning as expected—CLS adjust their power demand over their allowed flexibility range in correspondence with electricity price. A higher price leads to a lower CLS power setpoint, and vice versa. The results of these simulations should shed some light on whether aggressive light-level reductions or change rates (which run the risk of upsetting occupants) or fast-responding CLS (which might be prohibitively expensive to deploy) are needed to deliver significant grid services.

Lighting in the residential and commercial sectors consumes about 232 billion kWh of electricity each year. The availability of CLS (which had a 0.5 percent share of the installed base in 2016) is expected to grow rapidly to 52 percent of all installed luminaires in the commercial sector by 2025, according to a DOE forecast. The lighting industry is currently focused on developing CLS that deliver value to their owners, operators, and occupants, but not necessarily to the electrical grid—in large part because manufacturers and their customers either don't understand the value of grid services or don't believe that lighting systems are well suited for providing such services. Changing that can make a huge difference in overall energy consumption, as well as in grid reliability.

The continuing investigations by the DOE in this area will extend to other price profiles, buildings types, kinds of grid services, and coordinated control with building HVAC systems. Stay tuned.