Dimming Ballasts

Codes and Standards Enhancement (CASE) Initiative
For PY 2014: Title 20 Standards Development

Additional Test Data and Comments Regarding CEC Staff Report for Dimming Ballasts

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The California Investor Owned Utilities (CA IOUs) are submitting the following comments and data to provide support to the California Energy Commission (CEC) in its rulemaking to set minimum Title 20 appliance efficiency standards for dimming fluorescent ballasts. The information contained in this comment letter addresses outstanding concerns raised by dimming ballast manufacturers and is intended to be considered by the CEC as it develops its standards proposal.

1 3- and 4-Lamp Ballasts

In response to the Staff Report for dimming ballasts released by the CEC on April 14, 2014, as well as the CASE Report for dimming ballasts submitted by the CA IOUs on August 6, 2013, manufacturers have commented that the proposed standard levels disproportionately affect 3- and 4-lamp ballasts. The CA IOUs acknowledge that the proposed integrated ballast luminous efficiency (I-BLE) values, are higher for 3- and 4-lamp ballasts than they are for 1- and 2-lamp ballasts, but the *relative* stringency is designed to be roughly equivalent across all ballasts. The proposed standard curve increases for ballasts that operate more lamps because these products have an inherent advantage in achieving higher efficiencies. This is due to the fact that for all fluorescent ballasts, there are some fixed losses in the ballast electronics (switching losses due to transistors, fixed voltage drops across diodes, etc.) that are independent of variable losses (resistive losses). Both fixed losses and variable losses decrease ballast efficiency. Variable losses increase with more lamps, or more precisely, when more arc power is being delivered to the lamps; however, fixed losses are unrelated to the amount of arc power being operated by the ballast. Therefore, ballasts that operate more lamps, or at higher arc power, have a lower fraction of fixed losses, and are thereby inherently capable of achieving higher efficiencies relative to ballasts that operate fewer lamps. In its rulemaking for fixed output fluorescent ballasts, DOE conducted its own analysis of fixed and variable ballast losses based on empirical test data, and developed a similar relationship between BLE and lamp arc power.[1]

With respect to 3-lamp ballasts, the CA IOUs believe that the sample size of ballasts tested (10) was sufficient to allow for a fair evaluation of the stringency of the proposed standard levels. Particularly, when paired with test data from 1-, 2-, and 4-lamp ballasts, the relationships between ballast losses and lamp number fit the trends described above, where 3-lamp ballasts are generally more efficient than 2-lamp ballasts, with efficiency increasing even further at higher lamp arc powers. Two of the ballasts tested comfortably pass the standard levels proposed by the CA IOUs, and the remaining ballasts all fall within the expected band of efficiency for lamps at that arc power range, with the exception of a single non-CEE-listed ballast that significantly underperforms.

With respect to 4-lamp ballasts, the products that were tested by the CA IOUs do not necessarily represent the highest efficiency products on the market, nor do they represent the maximum achievable efficiency for that product class. The observation that the tested

[1] US Department of Energy. Final Rule Technical Support Document: Fluorescent Lamp Ballasts. November 2011. Section 3.4.1.

4-lamp ballasts are disproportionately affected by the proposed standard levels therefore does not create any justification for lowering the standard levels for 4-lamp ballasts. Some of the 4-lamp ballasts tested were actually less efficient than 2-lamp ballasts, which does not conform with what is understood regarding fixed and variable fluorescent ballast losses, as described above. The CA IOUs believe that the observed poor performance of 4-lamp ballasts only serves to further illustrate that manufacturers have not yet tried to fully optimize the efficiency of these products, which in turn provides further justification that significant energy savings can be captured through technically and economically feasible improvements to ballast efficiency.

2 T5 Ballasts

In response to the Staff Report published by CEC, manufacturers commented that T5 ballasts should be excluded from the scope of coverage, because no T5 ballasts had been tested, and therefore, no data was available to show that the proposed levels would be suitable for T5 ballasts. In response to this concern, the CA IOUs conducted additional testing of seven 2-lamp T5 ballasts (including products from different manufacturers and with different control methods) to verify their performance, finding that 2-lamp T5 ballasts are generally at least as efficient as 2-lamp T8 ballasts. The test results, in terms of I-BLE, are plotted below, along with the test results from 2-lamp T8 ballasts.

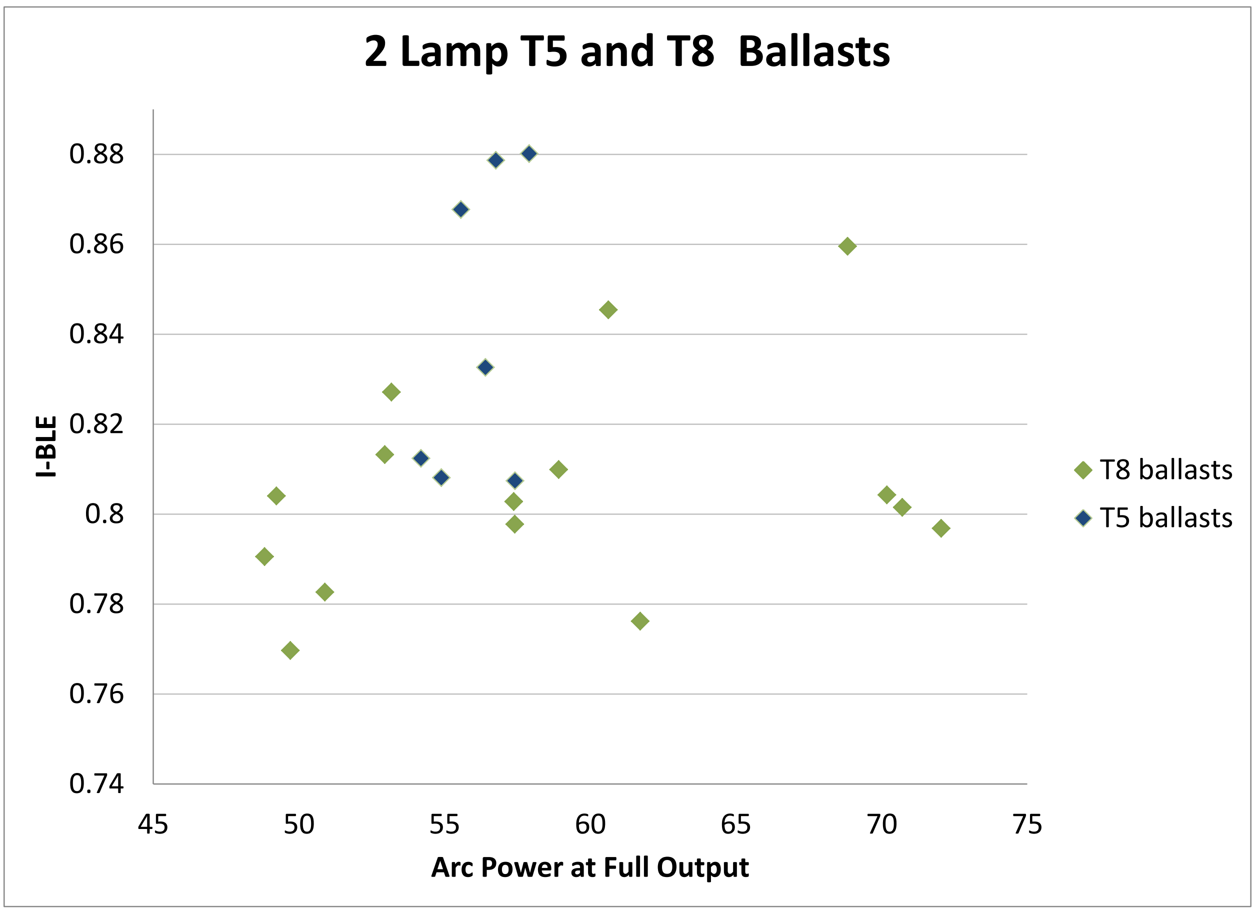

Figure 1. Plot of CA IOU test results from 2-lamp T5 and T8 ballasts.

As illustrated in the chart, three of the T5 ballasts tested are more efficient than any of the T8 ballasts tested. These results imply that T5 ballasts can be at least as efficient as T8 ballasts designed to operate the same number of lamps (and/or at the same arc power), and therefore, it would be appropriate to apply the standard level proposed for T8 ballasts to T5 ballasts as well. The full test results from the 2-lamp T5 testing are included for docket as a separate Excel file.

3 Power Factor

As stated in previous comments to CEC, the CA IOUs strongly support the adoption of minimum power factor requirements for dimming fluorescent ballasts. On commercial building lighting circuits, where these products are most commonly installed, there are clear benefits to ensuring high power factor ballasts, not only for the utility provider, but also the customer.

Added current through the circuit due to poor power factor creates additional losses in the wiring of a lighting circuit. Fluorescent fixtures are most commonly installed in commercial spaces with several fixtures branch wired on a circuit, with additional wiring runs to a central panel. These circuits are hundreds of feet in total wiring length. In a model of a typical commercial lighting system, with roughly 30 fixtures on 12 gauge wire in branch configuration, the total resistance of the wire is conservatively estimated to be around 0.11 ohms, depending on the configuration of system. In this simplified example, if each fixture draws 90 W of power at 277 V at full output, the difference between 0.5 power factor and the proposed standard of 0.9 power factor can mean a total added current of 8.66 amps, resulting in losses of 8.26 kWh per year at the circuit level. On a per-ballast basis, this equates to an increase in operating costs of about $1.20 over the 13 year design life of the ballast at a typical commercial lighting rate of $0.14/kWh. These additional costs would increase for 120 V systems, which are also common in both residential and commercial lighting circuits, because more current is required in 120 V circuits, which results in significantly higher resistive losses.

The following equations document the calculations performed in analyzing the cost of poor power factor in the model lighting circuit described above:

$$Apparent\ Power\ at\ Max\ Light\ Output = \frac{90W}{fixture} * 30\ fixtures = 2700W$$

$$Real\ Power_{0.9PF} = \frac{2700W}{0.9} = 3000W\ ;\ Real\ Power_{0.5PF} = \frac{2700W}{0.5} = 5400W$$

$$Current_{0.9PF} = \frac{3000W}{277V} = 10.83A\ ;\ Current_{0.5PF} = \frac{5400W}{277V} = 19.49A$$

$$Extra\ Current\ from\ Low\ PF = Current_{0.5PF} - Current_{0.9PF} = 8.66A$$

$$Circuit\ Power\ Losses\ at\ Max\ Light\ Output = Extra\ Current^2 * Circuit\ Resistance^* = 8.66A^2 * 0.11\Omega = 8.26W$$

* Where circuit resistance is calculated based on 12 gauge wire in a branch-wired lighting circuit, with standard 8ft x10ft fixture spacing and multiple fixtures on each branch, and with a wiring run to the electrical panel of approximately 50 ft. With greater fixture spacing, longer wire lengths, series configurations, etc., circuit resistance will increase, leading to greater losses.

$$
\begin{aligned}
&\mathit{Annual\ Circuit\ kWh\ Losses} \\
&= \mathit{Circuit\ Power\ Losses\ at\ Max\ Light\ Output\ weighted\ against\ assumed\ duty\ cycle} \\
&= \frac{8.26W * 100\% * 637h + 8.26W * 80\% * 1592h + 8.26W * 50\% * 955h}{1000} \\
&= 19.72kWh\ per\ year
\end{aligned}
$$

$$
\begin{aligned}
\mathit{Per\ Ballast\ Lifetime\ kWh\ Losses} \\
&= \frac{\mathit{Annual\ Circuit\ kWh\ Losses} * \mathit{Expected\ Ballast\ Lifetime}}{\mathit{Number\ of\ Ballasts}} \\
&= \frac{19.72kWh\ per\ year * 13years}{30\ ballasts} = 8.54kWh
\end{aligned}
$$

$$
\mathit{Per\ Ballast\ Lifetime\ Energy\ Cost\ Losses} = 8.54kWh * \$0.14/kWh = \$1.20
$$

The total cost of achieving 0.9 power factor for dimming fluorescent ballasts is expected to be under $0.50 per ballast. This is due to the fact that dimming ballasts are already equipped with relatively sophisticated integrated circuits to receive and respond to dimming signals, manage lamp currents, and perform other functions needed to effectively operate and dim fluorescent lamps. The need for added circuitry for power factor correction is therefore relatively minor from the perspective of silicon chip manufacturers. The only incremental costs of power factor correction for dimming ballasts would be the material costs of the added circuit components. In a typical lighting circuit such as the example presented above, these costs are fully justified when considering the customer-side wiring losses saved through power factor correction to 0.9 power factor.

Finally, it is important to note that the analysis presented above does not consider utility-side impacts of poor power factor, where grid-level correction becomes necessary. These additional impacts are significant to utility power providers, and to the extent that the costs of these impacts are ultimately passed through to customers, improving power factor on the customer side will also lead to additional savings on customer energy bills.