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NEC Acceptability of ETC UL Listed Dimmers Used at 100% Continuous Rating – Revised for 2011 NEC

Purpose:

The purpose of this application note is to educate Engineers and Authorities Having Jurisdiction (AHJs) on the NEC References to 100% continuous loading of branch circuits and how ETC deals with these conditions.

NEC References to 100% Continuous Loading of branch circuits:

- Article 100 of the NEC defines a continuous load as follows:

> ***Continuous Load:*** *A load where the maximum current is expected to continue for 3 hours or more.*

- Therefore, a *noncontinuous* load is one that continues for less than 3 hours.
- Section 210.20 (A) sets the requirements for branch circuit loading for continuous and noncontinuous loads:

> ***210.20 (A) Continuous and Noncontinuous Loads.*** *Where a branch circuit supplies continuous loads or any combination of continuous and noncontinuous loads, the rating of the overcurrent device shall be not less than the noncontinuous load plus 125% of the continuous load.*
>
> ***Exception:*** *Where the assembly, including the overcurrent devices protecting branch circuit(s) is listed for operation at 100 percent of its rating, the ampere rating of the overcurrent device shall be permitted to be not less than the sum of the continuous load plus the noncontinuous load.*

- This section dictates that it is not permissible to load a branch circuit with a continuous load larger than 80% of the branch circuit overcurrent device rating. This is because typical overcurrent devices are thermal/magnetic breakers, and the ambient temperature and the normal breaker tolerance have an effect on the trip current of the breaker
- However, the *Exception* states that if the device feeding the circuit is *listed for 100% of its rating*, along with its circuit breaker, it can be loaded continuously to its full rating.
- ETC Sensor, Unison, and SmartPack dimmers are UL Listed for 100% of their ratings, and can therefore have branch circuits loaded to 100% of the dimmer rating.

Background: Characteristics of Thermal/Magnetic Circuit Breakers

Traditional circuit breakers used to protect building wiring and also used in some well-known architectural dimmers are *thermal/magnetic* devices. To protect against overcurrent, they use a bimetallic element that heats and changes shape under load. In an overload condition, the bimetallic element actuates the trip mechanism of the breaker, opening the circuit. The magnetic portion of this type of breaker only kicks in under a short circuit condition to trip the breaker. UL requires breaker manufacturers to test to the UL489 standard for Molded Case Circuit Breakers. For this type of breaker to be used in an elevated temperature application such as a dimmer, the standard requires a breaker to carry its *continuous current rating* at an ambient temperature of 40°C (104°F) in free air. However, the trip curve of the breaker varies considerably with temperature.

Consider the example of a typical thermal/magnetic breaker such as a Square D type QO, 1-pole, 20 amp breaker that is calibrated at 40ºC:

Trip Time at 40°C for 60A, 3x rating overload condition:	Trip time at 25°C for 60A, 3x rating overload condition:
2 to 10 seconds	2 to 100 seconds

Why are some other manufacturers' dimmers with thermal/magnetic breakers only rated and Listed for 80% continuous loading?

The trip current and trip delay of a thermal/magnetic breaker are widely affected by temperature: the higher the ambient temperature, the lower the trip current and the shorter the delay; the lower the ambient temperature, the higher the trip current and the longer the delay. This temperature variation can be enormous, causing the trip point to range from 60% of the breaker rating at very high ambient temperatures, to 200% of the rating at very low ambient temperatures. In practical terms, there can be significant heat buildup in equipment during normal operation, which significantly changes the trip current and delay of the thermal magnetic breaker. As such, some manufacturers of dimmers with thermal/magnetic breakers choose to UL list their product for 80% continuous loading, because the breaker is not suitable for 100% loading. Per NEC section 210.20(A), circuits connected to this type of dimmer cannot be loaded above 80% of the dimmer rating.

Why do ETC dimmers have a 100% continuous load rating?

For performance lighting systems, a 100% continuous load rating has always been a requirement. Users want to be able to load a 2.4kW dimmer to 2.4kW, and leave it on as long as they like. ETC dimmers were originally designed with the performance lighting market in mind. ETC dimmer designs that allow 100% continuous loading are also widely used in the architectural market.

How do ETC dimmers achieve a UL-Listed 100% continuous load rating?

All ETC dimmers use a *magnetic/hydraulic* circuit breaker. This type of breaker uses a magnetic trip element that is unaffected by temperature, and has much tighter tolerances than a thermal/magnetic breaker. That means that a hot breaker and a cold breaker will always trip in the same time for a given overcurrent condition, and trip point consistency across a large quantity of breakers will be completely uniform. Magnetic/hydraulic breakers have many other advantages:

- No "cool-down" period after a breaker has tripped—can be reset immediately
- Can carry full rated current indefinitely at any ambient temperature
- Precise time delay to accommodate inrush current of cold lamps while protecting dimmer against short circuits

UL tests and lists ETC dimmers for 100% loading, which is achievable due a number of factors, including the higher quality and tighter tolerance of the magnetic/hydraulic circuit breaker.

ETC Application Note:

Understanding 100% Continuous Load Rating

Circuit Breaker Marking in ETC Dimmers

Some breakers in ETC dimmers are labeled with the "Must Trip" rating, which is 25 amps in the case of a 20 amp dimmer. The Must Trip rating describes the first point on the time delay curve of the breaker, which causes the breaker to trip in a time of between 7 and 100 seconds in the presence of 25 amps of current. The same breakers may also be labeled "FLA 20", which describes the Full Load Amps rating of the breaker—the current that the breaker will carry indefinitely without tripping. The range of overcurrent between 20.1 amps and 25 amps is one of indeterminate breaker behavior, which is why 25 amps is the first point on the curve, or the first level of overcurrent where the breaker must reliably trip.

Branch Circuit Conductor Sizing and Temperature Rating with ETC Dimmers

- NEC Table 310.15(B)(16) defines the ampacities of different gauge wires, in aluminum and copper, for wire temperature ratings of 60°, 75°, and 90° C. The higher the temperature rating, the greater the ampacity for a given AWG size (gauge) of conductor. This table also lists the wire types for each temperature rating (THHN, THHW, etc). It covers conditions where up to three current-carrying conductors are installed in a conduit or wireway.
- NEC table 310.15(B)(3)(a) gives the ampacity adjustment factors when more than three current-carrying conductors are installed in a pipe or conduit. This is the table of "normal" ampacity adjustment factors
- For many theatrical installations where diversity is common—where many loads are not connected at all or not turned on all at once—NEC Table B310.15(B)(2)(11) (in Annex B at the back of the Code) lists the ampacity adjustment factors for up to 85 wires in a pipe or wireway. (This number of wires is allowed in theatre installations by Section 520.6) Table B310.15(B)(2)(11) defines diversity, and offers less ampacity adjustment for a given conduit fill under the assumption that not all circuits are fully loaded or turned on simultaneously.
- As part of their UL listing, ETC Sensor and Unison dimmer racks require use of 90°C copper conductors, but used at not more than the 75°C ampacity rating of the conductor. This is because normal wire ratings are based on an ambient temperature of 30°C (86°F), and it is assumed that the interior of a dimmer rack will be hotter than that, requiring additional derating. In practical terms, this does not impose more restriction on a typical installation, and here's why:

  Example: Ten 20 amp circuits in a conduit connected to a Sensor Rack—20 current-carrying conductors.

1.	Required ampacity per conductor:	20 amps
2.	Ampacity adjustment for 20 conductors from Table 310.15(B)(3)(a):	50%
3.	20A divided by 50%:	40 amps
4.	Required 90°C conductor size for 40A per Table 310.15(B)(16):	#10AWG
5.	75°C Ampacity of #10AWG conductor	35 amps

  You can see that in a typical installation, using 90ºC wire and a larger conductor size to gain additional ampacity and conduit fill puts the actual ampacity (20 amps) far below the 75ºC rating of the wire (35 amps), thus automatically complying with the Sensor UL listing requirement for use of the 75ºC ampacity rating and 90ºC wire. This also applies to typical rack feeder conductors, where there are generally at least four current-carrying conductors in the pipe or wireway, causing 80% ampacity derating of conductors.

- With a phase-control dimmer system like Sensor or Unison, neutrals are always considered current-carrying conductors for the purpose of conduit fill and derating. This is because phase-control dimmers generate harmonics.
- Branch circuit wiring connected to ETC dimmers should be sized according to the UL-Listed 100% rating of the dimmer, utilizing NEC tables 310.15(B)(16), ampacity-adjusted for conduit fill by table 310.15(B)(3)(a) or table B310.15(B)(2)(11), if loads are typical cord-connected production lighting loads and have at least 50% diversity.

Additional Examples:

Four 20A architectural lighting circuits (8 current carrying conductors) in a conduit or wireway:

- Required ampacity per conductor: 20A
- Ampacity adjustment from table 310.15(B)(3)(a) for 8 current carrying conductors 70%
- 20A divided by 70% (required ampacity based on fill) 28A

Suitable 28A conductors from Table 310.15(B)(16): #12 AWG 90ºC Copper THHN

Thirty 20A theatre lighting circuits (60 current carrying conductors—allowed by section 520.6) in a conduit or wireway, with 50% load diversity:

- Required ampacity per conductor: 20A
- Ampacity adjustment from table B310.15(B)(2)(11) for 60 current carrying conductors with 50% diversity 50%
- 20A divided by 50% (required ampacity based on fill) 40A

Suitable 40A conductors from Table 310.15(B)(16): #10 AWG 90ºC Copper THHN

Conclusion

- The circuit breakers in ETC dimmers utilize a magnetic/hydraulic technology that allows the dimmer module to achieve a UL-listing for 100% continuous loading.
- Section 210.20 (A) of the NEC allows branch circuits connected to ETC dimmer to be continuously loaded to 100%, if desired.
- Branch circuit wiring connected to ETC dimmers should be sized according to the UL-Listed 100% rating of the dimmer, utilizing NEC table 310.15(B)(16), ampacity-adjusted for conduit fill by table 310.15 (B)(3)(a) or table B310.15(B)(2)(11), if loads are typical cord-connected production lighting loads and have at least 50% diversity.
- ETC 20 amp dimmers are UL-listed for 20 amps, 100% continuous loading in both theatrical and architectural installations, per NEC Section 210.20(A). ETC 50 amp dimmers are UL-listed for 50 amps, 100% continuous loading in both theatrical and architectural installations, per NEC Section 210.20(A). The marking of the “Must Trip” rating on the dimmer breaker does not alter this UL rating.