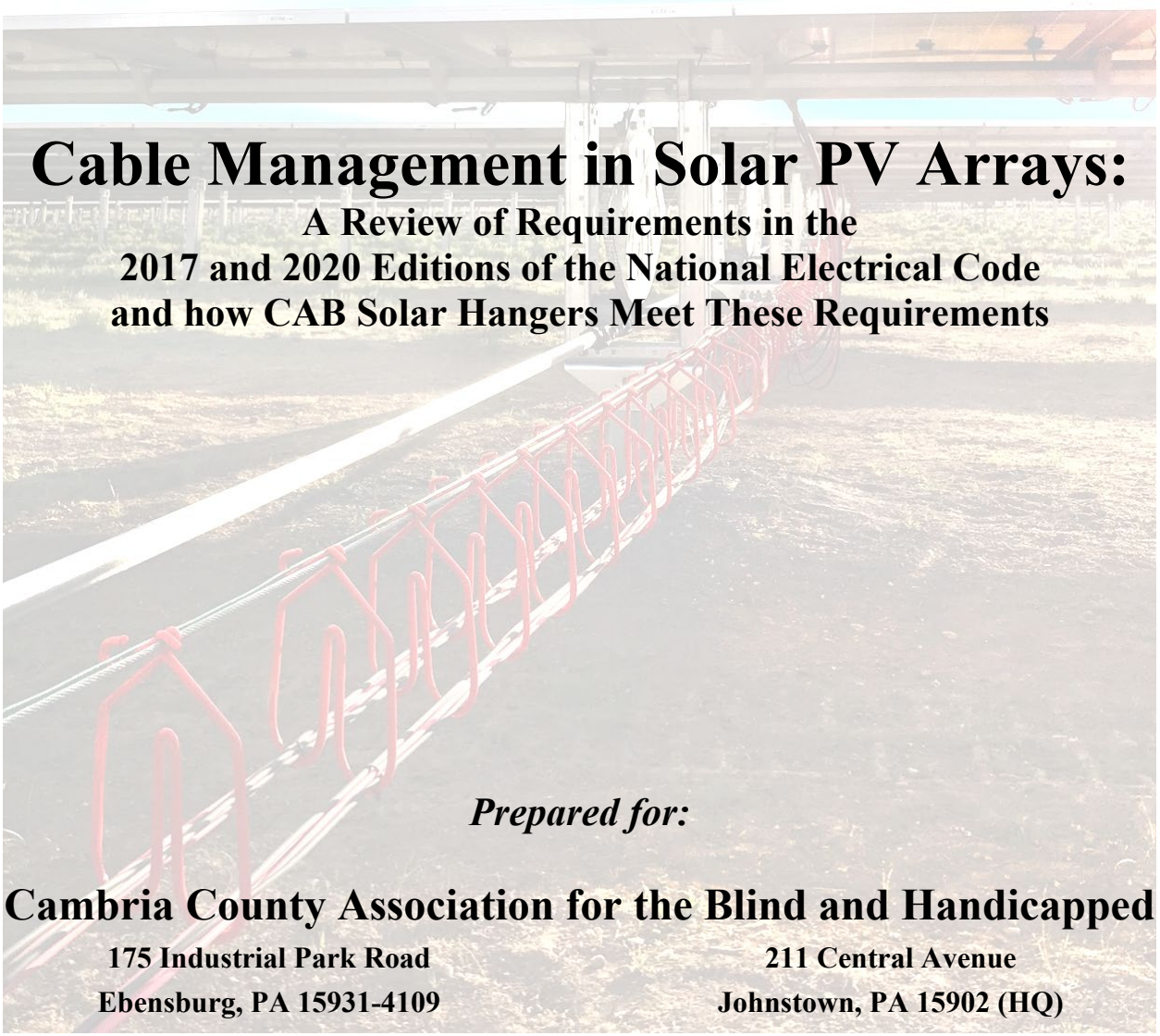

Cable Management in Solar PV Arrays:

A Review of Requirements in the 2017 and 2020 Editions of the National Electrical Code and how CAB Solar Hangers Meet These Requirements

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1 Introduction

Cable management is one of the most important aspects of the safety and longevity of nearly every photovoltaic (PV) system. This is primarily due to the extensive use of exposed cables used in the PV array. Since the equipment is installed outdoors on rooftops and in open fields, the electrical conductors must be rated for sunlight resistance and be supported and secured properly. Most electricians are referred to as “indoor wiremen” and are familiar with installing conductors in conduit, but have less experience working with exposed cables in power systems. These exposed cable power systems are common in the utility and petroleum industries and there are decades of experience with these types of systems. Since the National Electrical Code (NEC) does not regulate either of these industries, there is less emphasis in the NEC to guide these and similar types of installations.

While exposed cable management may not be a primary focus of the NEC, there are several references to such systems. There are also broad requirements for safe wiring practices that can be used to develop best practices for exposed cable systems in solar PV systems. This document lays out the basic requirements found in the 2020 and 2017 editions of the NEC and relate these requirements and industry standard installation practices to CAB Solar Hangers.

2 Review of NEC Requirements and Installation Standards

The primary aspects of this review will focus on the installation of the CAB Solar Hangers used for cable management in a solar PV array. Proper methods for exposed cable management is ultimately an issue of approval by the authority having jurisdiction (AHJ). That approval is generally based on the application of the National Electrical Code (NEC) and electrical installation standards. A common thread in the installation of electrical systems is that the work be done in a neat and workmanlike manner [NEC 110.12] and that conductors are not exposed to physical damage [NEC 300.4].

> ***110.12 Mechanical Execution of Work.*** *Electrical equipment shall be installed in a neat and workmanlike manner.*
>
> *Informational Note: Accepted industry practices are described in ANSI/NECA 1-2015, Standard Practice for Good Workmanship in Electrical Construction, and other ANSI approved installation standards.*

> ***300.4 Protection Against Physical Damage.*** *Where subject to physical damage, conductors, raceways, and cables shall be protected.*

Physical damage is not specifically defined in the NEC or in ANSI/NECA 1. However, it is generally understood as being self-defined. Preventing physical damage to electrical equipment in a parking garage may mean installing parking curbs, bollards, or cages to keep cars from running into it [NEC 100 Enclosure, NEC 110.27(B)]. For conductors it is also highly location specific and physical damage would mean obvious items that could damage the insulation on a conductor. This would include chafing on sharp edges, vehicle traffic, and vandalism depending on the installation. The NEC requires overhead cables to be installed 10 feet above finished grades or sidewalks [NEC 225.18] where accessible to unqualified people. In a large PV power plant, the perimeter fencing and security system that keeps unqualified people out of the facility is sufficient to prevent contact by unqualified persons. However, since vehicles often need to be used within the PV array, care should be taken in the design to prevent damage from vehicular traffic. This would include following rules for overhead conductors should vehicles be required to travel under cable management systems.

Given the large amount of exposed cable used in PV arrays, it is understandable that wiring methods are as simple and cost effective as possible to keep installation and

maintenance costs to a minimum. This often creates differences of opinion as to whether exposed cables are installed in a neat and workmanlike manner that is free from physical damage. During the past 20 years when PV systems have predominantly used exposed dc cabling systems—many of the concerns over installation practices revolve around exposed cable management in the PV array.

2.1 Installation Standards in ANSI/NECA 1

Since the NEC references ANSI/NECA 1 in the informational note for NEC 110.12, it is helpful to review that installation standard for any information that may be relevant to industry standard practice in this area. Chapter nine of this standard in entitled "Wire and Cable" and includes the relevant information. In the opening clauses in chapter nine there are several simple and clear statements regarding cable management:

c) Wire and cables shall be installed so as not to damage the insulation or cable sheath.

h) Cables that are installed exposed shall be run parallel and perpendicular to the surface of the building or exposed structural members and follow the surface contours as much as practical.

i) Running boards shall be used where necessary to provide sufficient support and a neat installation. Care shall be taken to provide sufficient mechanical protection for exposed cables.

j) All wires and cables, whether exposed, concealed or in raceways, shall be sufficiently supported using devices intended for the purpose.

Item "c)" above is self-explanatory. Cable damage is unacceptable because of the obvious hazards of energized conductors. Items "h)" and "i)" do not relate directly to cable hangers or CAB Solar Hangers, but they are relevant in that they address the neatness of an installation and the importance of mechanical support of exposed cables. Lastly, item "j)" focuses on the intended purpose of supporting devices. An installer may argue that a piece of coat hanger or bailing wire could support a cable, but these devices are not intended for the use. A similar issue could be made of an electrical support item not used in its intended use. For instance, a one-hole conduit strap designed to support a 1" EMT conduit could support an exterior cable. However, that device has sharp edges intended to help hold the conduit that can cause cable damage. The one-hole conduit strap device should not be used as a cable hanger since it is not intended for that use and can damage the cable insulation. This violates two directives of the installation standard.

Lastly, there is a specific directive in the ANSI/NECA 1 standard related to securement and support with cable ties.

> *q) When using cable ties, do not over tighten, to ensure the cable tie does not cut the conductor's outer jacket. Cable ties shall not be used to support raceways or cables.*

It is the recommendation of this standard that cable ties are not used to support cables. It is common to see cable ties used in PV installation as the sole method of support. While it is not specifically disallowed in the NEC, this industry standard does not allow it. This clause also warns against the common mistake of overtightening cable ties to the point where they could damage the cable jacket. In summary, the requirements in the ANSI/NECA 1 installation standard are common sense items that state that exposed cables should be supported and secured in such a way that the cables are undamaged, neat, and supported and secured by devices intended for cable support.

2.2 Requirements Relevant to Cable Management in the NEC

The 2020 and 2017 editions of the NEC have some direction on the support and management of exposed cables. Article 690 of the NEC, Solar Photovoltaic Systems, allows single conductor cable USE-2 and PV Wire to be installed in exposed locations within the array [NEC 690.31(C)(1)].

2.2.1 2017 NEC Cable Support Requirements

The installation methods for the exposed USE-2 and PV cable is stated in NEC 338.10(B)(4)(b) and 334.30 in the 2017 NEC. USE-2 cable is commonly used in PV array and is very similar to the PV Wire also used in many PV arrays which is why it is mentioned in the same section in 690.31(C)(1) in the NEC. Article 338.10(B)(4) refers the installer on to Article 334.30 for support methods. Article 334 is entitled Non-Metallic Sheathed Cable (often referred to by the trade name Romex) and includes these requirements for cable management in 334.30:

1. *Supported and secured by staples, cable ties, straps, hangers, or similar fittings at intervals that do not exceed 4.5 feet*
2. *Secured within 12 inches of each box, cabinet, conduit body, or other termination*

The provision for securement within 12 inches of a box is very well understood for NM cable in residential construction. The analogue in a PV array could be compared to the entry into a conduit system going underground or to a combiner box. These are subjective

evaluation criteria and require the AHJ to provide their approval of the support methods.

2.2.2 2020 NEC Cable Support Requirements

The 2020 NEC removes the references to Article 338 and 334 and has all the requirements for cables in 690.31(C). It simply states directly the requirements for exposed single-conductor cables in 690.31(C)(1).

> *…Exposed cables shall be supported and secured at intervals not to exceed 600 mm (24 in.) by cable ties, straps, hangers, or similar fittings listed and identified for securement and support in outdoor locations.*

Following both support and securement requirements outlined in Article 690.31(C)(1) for cable hanger installations is a well-founded approach for both the 2017 and 2020 editions of the NEC. For installations required to meet the 2017 NEC, this means that cable hangers should be placed at 24” intervals and the cables secured to the hangers using cable ties at every other hanger (4 feet between securements). The 2020 NEC requires support and securement at 24” intervals which is at each hanger at 24” spacings. Given the mechanical strength of multiconductor cables, the 2017 and 2020 NEC would allow greater than 24” between hangers for support as long as the product was listed for greater support spacing. For both Code editions, the securement distance should not increase past six feet [2017 NEC 690.31(D); 2020 NEC 690.31(C)(3)]. For cables of 1/0 AWG and larger, spacings greater than 24” are common due to the much higher mechanical strength of larger cables. Since many of these installations will fall under Article 691, Large-Scale PV Electric Supply Stations, the requirements of 690.31(C) can be superseded by engineering supervision that may allow larger spacings while still preventing cable damage.

Since many ground-mounted PV arrays have tracking systems that use ac power to drive the tracker systems, an installer may want to install the ac conductors in the same cable support system with the dc conductors. In the 2011 NEC and prior versions of the NEC, it would be acceptable to have the cables in the same saddle as long as the conductors are bundled separately [2011 NEC 690.4(B) and NEC 690.4(B)(4)]. However, there is a significant change in the 2014 NEC that disallows dc and ac conductors, even when part of the same system to be installed in the same raceway or enclosure unless they are separated by a partition. The same messenger wire could be used, but a different type of hanger or saddle would be necessary to separate the dc and ac cables. Figure 1 shows one method to separate the dc wiring from the ac wiring. Another hanger design that would

Figure 1: Two Cable Systems on the Same Messenger Wire

accomplish the same separation objective is shown in Figure 2. In Figure 2, the cable hanger has several separate sections to separate dc and ac, as well as provide for communications and other cable needs.

Figure 2: Multi-Carrier CAB Solar Hanger

This concept shown in Figure 2 provides for four different types of exposed cables. The same coated wire is used to create three main cable sections for the dc and ac conductors, but a fourth section at the top of the hanger is provided to install a communications cable.

This additional section is important since the required communications cable may not be of the same voltage rating as either the dc or ac cables. Since the communications cable is kept separate from the dc and ac cables, the voltage rating of the communications cable need only be sufficient to withstand the voltage of the communication circuits. This additional section can have a significant value for the support of exposed cables since the code would require that the communications cable have sufficient voltage ratings for any conductors it contacts. Both of the designs shown in Figures 1 and 2 are available from CAB Products.

2.3 Torque Tube Hangers

A new addition to the CAB Products family of solar hangers is the Torque Tube Hanger. Given the continued strong growth in tracking systems for PV systems, hangers that use the torque tube for support, rather than a messenger wire can be a simple and cost-effective way to support cables running parallel to the main support torque tube. Since these torque tubes often rotate 90 degrees or more when tracking east to west, the hanger must encircle the cables to keep them in the hanger. Figure 3 shows an example of a typical CAB Torque Tube Hanger installation.

Figure 3: Torque Tube Hanger Supporting String Conductors

3 Grounding and Bonding of Cable Supports

The electrical industry, including code enforcement personnel, are heavily focused on grounding and bonding of metallic parts. The primary concern is contact of exposed metal parts with conductors having damaged insulation—thus energizing the metal parts. Consider a cable hanger like the CAB Solar Hangers shown in Figure 2. These types of Solar Hangers would fall under that definition of "fitting" in Article 100 of the NEC.

> ***Fitting.*** *An accessory such as a locknut, bushing, or other part of a wiring system that is intended primarily to perform a mechanical rather than an electrical function.*

As an example, metallic cable staples for NM cable are not required to be bonded. The NEC simply states in Article 334.30 that, "*Nonmetallic-sheathed cable shall be supported and secured by staples, cable ties, straps, hangers, or similar fittings designed and installed so as not to damage the cable*…" (highlight added for emphasis). Clearly, damage to the cable is the issue. Since cable hangers are clearly referred to in a list of fittings, CAB Solar Hangers are not required to be bonded and do not need a listing for bonding and grounding. Additionally, the CAB grounding messenger wire has been evaluated as both an equipment grounding conductor (EGC) and grounding electrode conductor (GEC) but this certification is to reduce costs for equipment grounding of the structure and equipment, not to bond the cable hangers.

Ultimately, the AHJ must approve any equipment used in a PV installation under their purview. Most, if not all Solar Hangers are coated with a durable non-conductive coating designed to prevent damage to the cable. This prevents the metal of the hangers and saddles from coming in contact with the cable as shown in Figures 4.

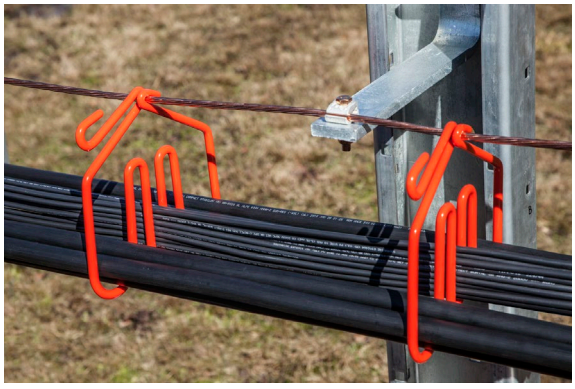

Figure 4: CAB Solar Hangers with PVC Coating

4 Ampacity of Conductors Bundled in a Cable Support

Another important concern of the AHJ is the ampacity of the conductors. Clearly, a USE-2/RHW-2 or PV Wire/RHW-2 installation such as the one shown in Figure 1 should be considered as a messenger wire supported installation and subject to the messenger wire ampacity table, Table 310.15(B)(20) [Table 310.20 in the 2020 NEC], for ampacity values. This table, according to note (2) of Table 310.15(B)(20), covers a bundle of up to three conductors. However, as cables are further bundled together, as in Figure 4, the inner conductors are not exposed to air and note (2) references Table 310.15(B)(3)(a) [Table 310.15(C)(1) in the 2020 NEC] for adjustment factors. Therefore, to be conservative, a cable bundle of more than three cables would be subject to the adjustment factors of Table 310.15(B)(3)(a) [Table 310.15(C)(1) in the 2020 NEC] which is used for more than three current carrying conductors. Since outdoor ambient design temperatures may exceed 40°C in some parts of the United States, an additional correction factor for temperature should be applied according to Table 310.15(B)(2)(b) [Table 310.15(B)(2) in the 2020 NEC] in very hot locations.

Lastly, it should be noted that Table 310.15(B)(20) [Table 310.20 in the 2020 NEC] only covers conductors down to size 8 AWG. For 10 AWG and smaller conductor installations of two or more single-conductor cables, it is recommended that Table 310.15(B)(16) [Table 310.16 in the 2020 NEC] be used for ampacity even though this table is likely very conservative. Where more than three conductors are in a bundle, the adjustment factors of Table 310.15(B)(3)(a) [Table 310.15(C)(1) in the 2020 NEC] would apply. The correction factors of Table 310.15(B)(2)(a) [Table 310.15(B)(1) in the 2020 NEC] would also apply to ambient design temperatures above 30°C in many locations in the United States.

For large-scale PV electric supply stations evaluated under Article 691 of the NEC, the cable ampacities may be modified under engineering supervision to better model the actual heating of the conductors. As stated above, Table 310.15(B)(16) [Table 310.16 in the 2020 NEC] is very conservative and is likely to underestimate the ampacity of a cable. Proper computer modeling under engineering supervision may validate higher ampacities of conductors. Keep in mind, the conservative nature of Table 310.15(B)(16) [Table 310.16 in the 2020 NEC] is primarily intended to protect conductors installed in buildings that could become a fire hazard if damaged by heat or other factors.

5 Summary

In summary, the use of purpose-built products like the CAB Solar Hangers for the exposed cable management in a PV array is well substantiated by the NEC and industry installation standards. Multiple sections, such as those in various configurations of CAB Solar Hangers, create effective separation of conductors that allow for dc, ac, and communications cables to be supported with a single hanger type.

CAB Solar Hangers are fittings as defined by the NEC and do not require bonding. Whether metallic hangers require bonding may be an item of dispute with some AHJs, so the cable management design should be communicated to the AHJ and approved prior to ordering the cable management equipment. The use of PVC-coated CAB Solar Hangers should avoid any damage to a properly installed cable system and the CAB Grounding Messenger Wire can provide for equipment bonding and grounding as needed in the PV system.

Ampacity of bundled cables as small as 8 AWG in a cable management system should follow Table 310.15(B)(20) [Table 310.20 in the 2020 NEC] and should be corrected by Table 310.15(B)(2)(b) [Table 310.15(B)(2) in the 2020 NEC] for ambient temperatures above 40°C and adjusted by Table 310.15(B)(3)(a) [Table 310.15(C)(1) in the 2020 NEC] when more than three conductors are in the bundle.

This concludes the Brooks Engineering assessment of the code compliance of the CAB Solar Hangers cable management equipment. Questions about the details of this evaluation should be addressed to Bill Brooks of Brooks Engineering at bill@brooksolar.com.