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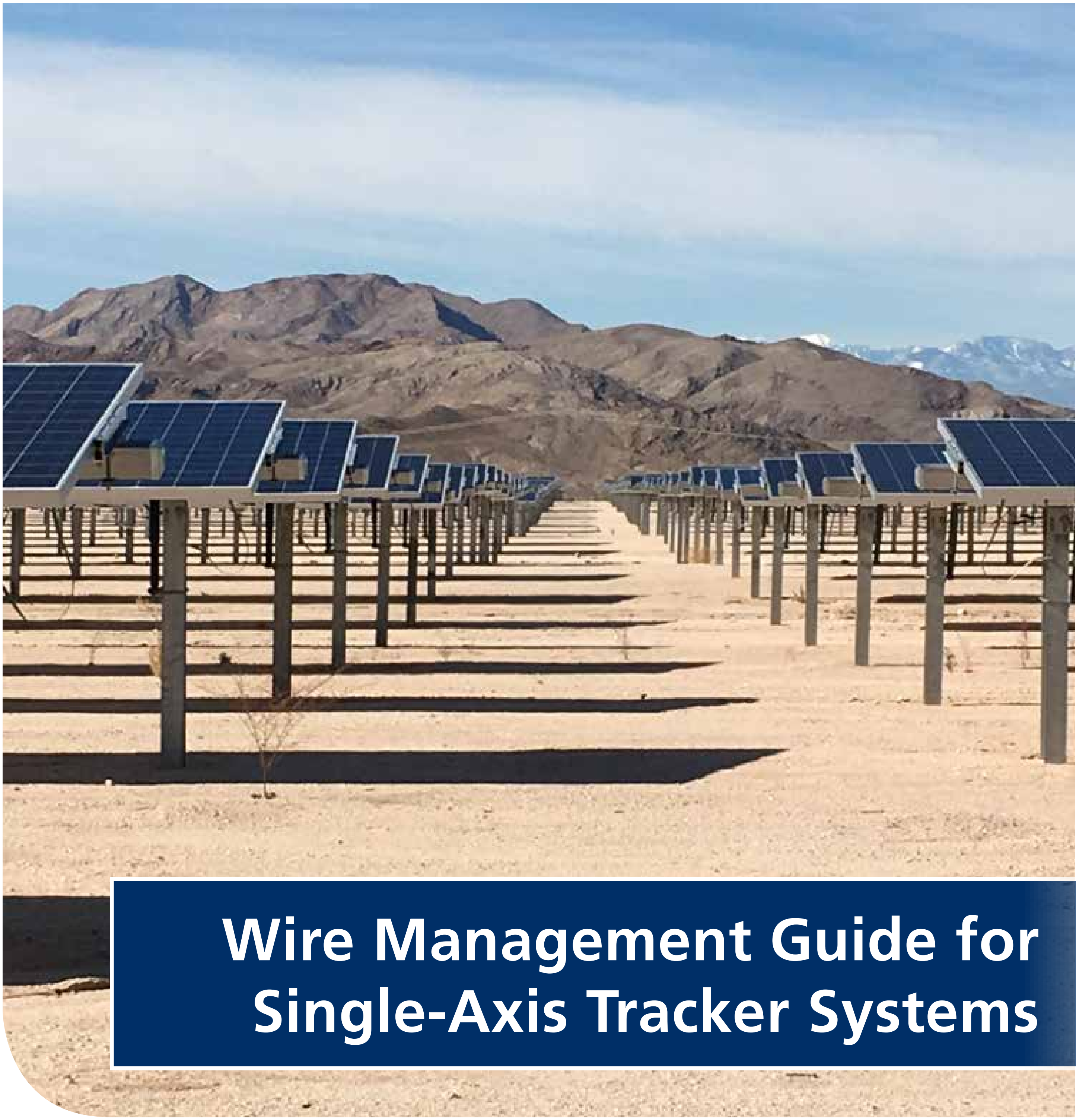


Wire Management Guide for Single-Axis Tracker Systems

Updated to Include:

Bifacial and Split J Box Modules

Wire Management Guide
For Single-Axis Tracker Systems

Scope of This Guide

While managing wire and cable on a single-axis tracker system is relatively straight forward, this wire management guide will help designers and installers avoid some common pitfalls of utility-scale wire management. Many of the recommendations in this guide are general best practices for all solar installations, while others are specific to single-axis trackers.

On a tracker system, module level wiring, or string wiring, is typically managed by attachment to the module itself. Several guidelines and techniques are discussed. Also covered are tips and techniques to manage cables between in-line trackers and from trackers to fixed structures, such as posts. Not discussed is row-to-row cable management, as that is dependent on many factors (geology, climate, access considerations, owner preference, etc.) and not within the scope of this guide.

Technical Considerations of Single-Axis Trackers

PV cable is generally managed along the axis of the tracker close to the horizontal location of the junction box. This management requires affixing to the module structure itself as PV whips are typically not long enough to allow attachment to the tracker structure. This can present complications as modules lack standard dimensions for both mounting holes and frame profiles.

Single-axis trackers follow the sun throughout the day. Trackers can have as much as a 60-degree range of motion and full rotations over 4000 times a year. This slow but steady movement must be considered, since inappropriate wire management will come loose or be severed if close to sharp metal edges, or be pulled apart if inadequate slack is given.

This movement presents two complicating factors for wire management. First, wire management design must consider this movement as it shifts gravitational pull on a fixing mechanism throughout the day (we refer to a fixing mechanism as the part of a wire management device that attaches to the module – metal teeth, fir tree, etc.). Wire capture mechanisms (we refer to a wire capture mechanism as the part of a wire management device that retains the wire – slot in metal clip for cable, cable tie or plastic clasp, etc.) on these systems must also account for this shifting gravitational pull. Second, as strings of cable are managed from the tracker (which moves) to fixed structures on the ground (that do not move) and from tracker to tracker (which both move but consideration must be made for the possibility that they may not move in unison), tension on cables must be considered.

Solar site conditions vary considerably, but several factors can be counted on as constants. First, solar sites have a high degree of UV exposure. Much of the wire management on a tracker will be sheltered from direct UV exposure but will still suffer from indirect exposure. Some wire management will face direct exposure all day long and materials must be chosen accordingly. Second, wires will be subject to movement due to wind, thermal expansion and contraction (which can move wires up to 3 inches in a single day) and tracker movement. All wire management must be designed and engineered with these points in mind.

Material Choices

There are two choices for wire management material: metal or plastic. Some solutions utilize both. Most metal wire management solutions are made of stainless steel or a corrosion-resistant spring steel. These systems have the benefit of a long service life, often exceeding the life of the PV array itself. The downside of metal wire management parts is that metal is conductive. If a cable becomes nicked by the fastener, a short or other type of fault can occur. A cut in the PV cable is more likely if the edges of the metal clip are sharp, not rounded or coined. Another contributing factor is when cables are pulled too tightly against the metal edge of a clip or tie, either through poor installation or inadequate allowance for movement. A cut in the wire is also more likely on a single-axis tracker, as the tracker is tracking during the day, creating a sawing motion and exacerbating any potential rubbing of cable jacket to metal.

Plastic components are also a popular choice. They have the inherent benefit of being non-conductive and, therefore, help mitigate electrical incidences on the array. Plastic is softer and less likely to slice through a cable jacket. There are many types and grades of plastic available on the market and understanding them is key to choosing one appropriate for your installation. Plastic generally does not have the service life of metal but is often chosen as a safer cable management material. Minimizing O&M costs requires choosing plastics that are engineered for tough solar conditions. Climate and site conditions should be considered in choosing the best possible plastic. What are the hot and cold extremes likely to be, is the location dry or humid, will the part be receiving direct or indirect UV exposure? Consult HellermannTyton for the best options for your installation.

In the image above, effort was made to protect the cable jacket from potential abrasion from a metal cable tie. The fear is that this small piece of insulation may erode or slip and leave the cable jacket exposed to the metal tie at an unfortunate angle.

Material Environment Factors:

- Chemicals: These can come from many sources, i.e. weed or dust suppressants.
- UV Exposure: Most of the UV is indirect, but proper UV additives like carbon black and UV stabilizers need to be factored for a long life. A UV rated versus a UV stabilized tie is a drastically different designation. Nylon parts are made appropriate for solar applications in large part by how they hold up to the sun’s deleterious effects. Carbon black is a major component that turns the part black and helps to absorb UV radiation. A black, UV rated part can have as little as 0.3 percent carbon black, while a more suitable UV stabilized part will have, at a minimum, 2 percent. HellermannTyton HIRSUV nylon 66 material can last 3 to 5 times longer in solar environments than a basic black, UV rated tie.

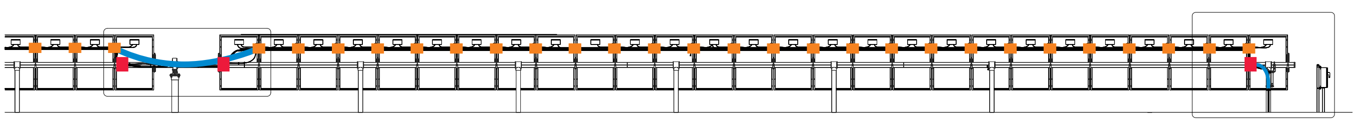
- Galvanization: Galvanized steel releases zincs and other chemicals that can react to plastics. Acid rain can also have an impact. Choosing materials with low or non-hygroscopic properties is important.
- Humidity: Non-hygroscopic materials absorb less moisture, which can help prevent degradation. This factor is becoming more important as the tracker market expands into areas like the Southeastern U.S., where humidity is prevalent.
- Temperature resistance: Plastic engineered for solar applications should generally have a high tolerance for temperature extremes and fluctuations. Heat stabilizing additives are often used to achieve this tolerance and extend the life of plastics at higher temperatures.
- Testing: As new plastics are introduced every year, it is wise to request accelerated testing data to ensure proper material development occurred.

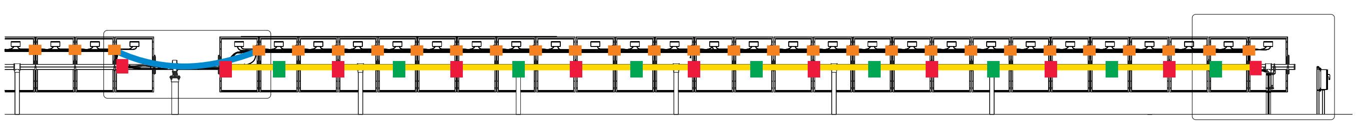
Vinyl coating separating from stainless steel cable tie.

Image shows blue coating fading from stainless steel cable tie.

Vinyl-coated stainless steel cable ties present another possible solution to wire management. Extreme care must be taken on tracker applications, however. While coated steel parts offer the promise of the stainless steel's long life and durability with the nonconductive insulation of the coating, these parts frequently fail in solar applications. Most failures occur when the coating peels, fades or is rubbed off the steel. This leaves the wires exposed to the metal edge of the cable tie – with the tracker's daily movement increasing the probability of the tie sawing through the wire jacket, creating the opportunity for a ground fault.

Wire Management Overview





KEY:

- Ratchet P-Clamp | *Part: 151-01475*
- E-Clip | *Part: 156-02225, 151-00982*
- Home Run Bundle
- Heavy Duty Cable Tie | *Part: 111-01196*
- CTPUV | *Part: 904-00357*

Proper Wire Management Installation Techniques

Manufacturer Installation Guidelines – It is best practice to follow manufacturer installation instructions when installing parts. This helps avoid improper installation and maintains manufacturer product warranties. In addition, always consult manufacturer specifications or electric code with respect to allowable bending radiuses for any conductors. This is also important for bending radiuses of wires emanating from the module junction box.

Proper Sizing/Load Ratings – Wire management solutions come with tensile strength ratings, usually expressed in pounds or newtons. These ratings must be considered as a starting point for determining strength requirements. Solar tracker installations require slack to be left in wires to combat thermal expansion and the transition of moving structure to non-moving structure. This slack presents opportunity for wind to exert force on cables, increasing the loads on the wire management device. Situations such as birds perching on wires must also be considered. Degradation of the fastening device must also be accounted for; it will not be as strong in 10 or 15 years as it is at the time of installation. Be aware of temperature issues. Ties in extremely hot or cold temperatures will degrade faster. A reasonable safety rating is 3 pounds per foot with a HellermannTyton E-Clip, but many factors play into your safety rating.

Mounting bases – While easy, running a cable tie through a module hole is not a long-term solution. The constant movement of the racking and wires throughout the day creates a sawing effect on the cable tie. A much better option is to use a mounting base, like a fir tree, arrowhead or edge clip to attach onto the module edge or hole. Having a fully locking tie or clip with a mounting base allows the wire to move throughout the day while fully securing the cabling away from the hole as well.

Strain Relief and Fixing Tension – Wires on solar installations contract and expand throughout the day and are subjected to wind load. Space must be provided for the wires to overcome these near-constant forces. In general, an increase in the number of attachment points and a decrease in the tension on wires provides the best solution. Wires need to move slightly, but too much slack allows the wind to apply greater force to them. Also, over tightening of cable ties can, over time, cut into wire jackets. One best practice is a two-finger approach; leaving a gap of two fingers allows for wire contraction due to thermocycling and helps to avoid over tensioning.

Avoid Contact with Metal Structures – Whenever possible, wires should be protected from any metal edge, especially sharp edges. This includes preventing contact with these metal edges in a wind event or when trackers are at any possible angle. It is advisable to include a standoff or a clip that lifts and separates the bundle from direct contact to provide a physical barrier between wires and metal structural components. Often, a properly engineered and UV stabilized piece of convoluted tubing (smurf tube) or split-loom (snake skin) may be used to protect the wires. But take extreme care to properly fasten the tubing as, too often, it moves in the field and exposes the wires it was intended to protect.

Other Notes – Many additional precautions must be taken into account:

- Clip tie ends – avoid situations where a clipped cable tie end can contact the backsheet of the module; this can lead to module issues. While long cable tie tails can be considered ugly, they will do less damage to wires, modules and fingers. Or, use a properly engineered cable tie cutting tool that will leave no sharp edges.
- Prevent wire from contacting the back of the module. This area gets extremely hot and can degrade wire insulation. Also, it can cause hot spots on the module, reducing module efficiency and lifespan.
- Make sure the module's connectors are located in areas where rain, ice and snow will not affect them. Water entering these devices can cause premature failure.

Module Level Wire Management

Single-axis trackers are engineered to minimize excess materials; therefore, there are few structural features to affix wire management parts. Attaching wire to the module frame is the most efficient means of properly securing PV cable.

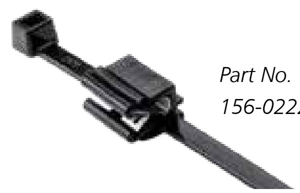
Possible attachment solutions are presented below:

Module Mounting Hole/Slot – Parts designed specifically for the module's mounting hole are highly recommended. It is NOT acceptable to secure PV wires by running cable ties through the module mounting hole. This is one of the most common causes of premature failure on solar installations and an exacerbated problem on single-axis trackers, as the punched hole in a module frame can be sharp and will quickly sever a cable tie, regardless of material. Appropriate options include arrowhead and fir tree fasteners designed to properly fit the module mounting hole.

Module Frame Rail – Module frames are most often anodized or painted aluminum and generally have tight thickness tolerances. Many manufacturers make clips to attach to the frame rails and have the capacity for one to multiple PV wires. Many off-the-shelf solutions are stainless steel, which present the benefits and downsides highlighted in the prior Material Choices section. Several manufacturers offer separate module attachment clips and an attachment point for a cable tie. While these solutions offer stronger grabbing force of metal to metal and nonconductive wire protection of a plastic cable tie, care must be taken to ensure the metal of the clip will not saw through the cable tie over time and that the cable tie itself is properly rated for a solar application.

Frameless Modules – Glass-on-glass or otherwise frameless modules present their own unique challenges. MIB rails provide attachment points for edge clips, but the rails provide very thin attachment points. A low profile clip is needed to provide a long-term solution. Check with your module supplier or wire management supplier for appropriate options.

The nylon cable tie looped through the module hole is unlikely to last more than a year or two on a single-axis tracker application.



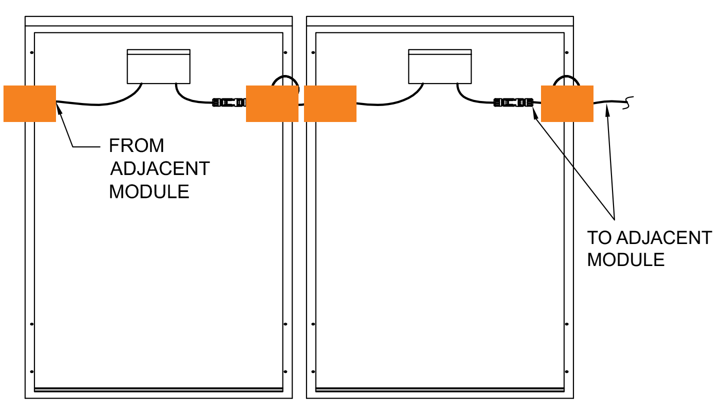
Part No. 156-02225

Part No. 151-00982

Part No. 151-02436

Part No. 151-02189

Part No. 151-02218



KEY:

E-Clip | *Part: 156-02224, 151-00982, 151-01699, 151-02189, 151-02218*

Tracker-Level Wire Management

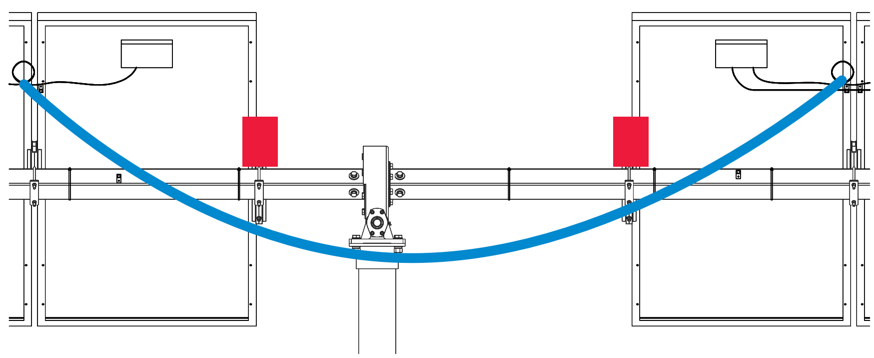
End-of-Row Arrest Mechanism — On a single-axis tracker, the most vulnerable area for wire management failure occurs where the string bundle is heaviest or a transition is made to a fixed point. This typically happens at the end of a tracker row or where a jump is made to an adjoining tracker, down to the torque tube, or where the bundle is transitioned to a fixed post. This is a vulnerable transition for a few reasons. First, the wire bundle is often heaviest (includes home run cables). Second, there is a torsional force on the bundle as its direction changes throughout the day when the tracker moves and changes the direction of downward pressure. Third, a bending force exists as the direction of the bundle has changed to allow it to move from being parallel to the tracker to being perpendicular. An arrest mechanism refers to a heavy duty fastening mechanism designed to provide increased support for this weak point. A typical failure scenario seen on utility-scale installations is a "zipper" type failure. This occurs when the weakest point fails and places even greater stress on the next support, causing it to break as well, and so on. The arrest mechanism seeks to minimize this wire management failure point and subsequent catastrophic failure of an entire tracker's module strings.

Part No.
151-01475

Managing Wire in Transitions

From Module to Torque Tube
Wiring can be fastened to the torque tube as it transitions from the module to either the adjacent row or to the post. This fastening is most often accomplished with a torque tube tie (heavy duty cable tie capable of reaching around the entire torque tube and accommodating the PV bundle) or an affixed clamp. One affixation point could be the bolt for the spacer plate near the module or torque tube or a P-clamp attached with a self-tapping screw. This measure is an effort to minimize the amount of free floating wire on the array and subsequent damage that might be caused from wind or other forces. A torque tube tie for a typical tracker must be at least 21" long and should have a minimum strength rating of 150 pounds.

Attached to MIB or Module



KEY:

- Ratchet P-Clamp | *Part: 151-02475*
- CTPUV | *Part: 904-00357*

From Tracker Row to Next Row

Managing bundles as they jump from one tracker to the next presents unique challenges. Not only is the bundle subjected to tracker movement at the beginning and end of the "jump," but it should be fastened along the post between, which does not move. The wire bundle must also be kept clear of the tracker gearbox and driveline throughout the entire range of tracker rotation. Furthermore, there should be no place for birds to perch.

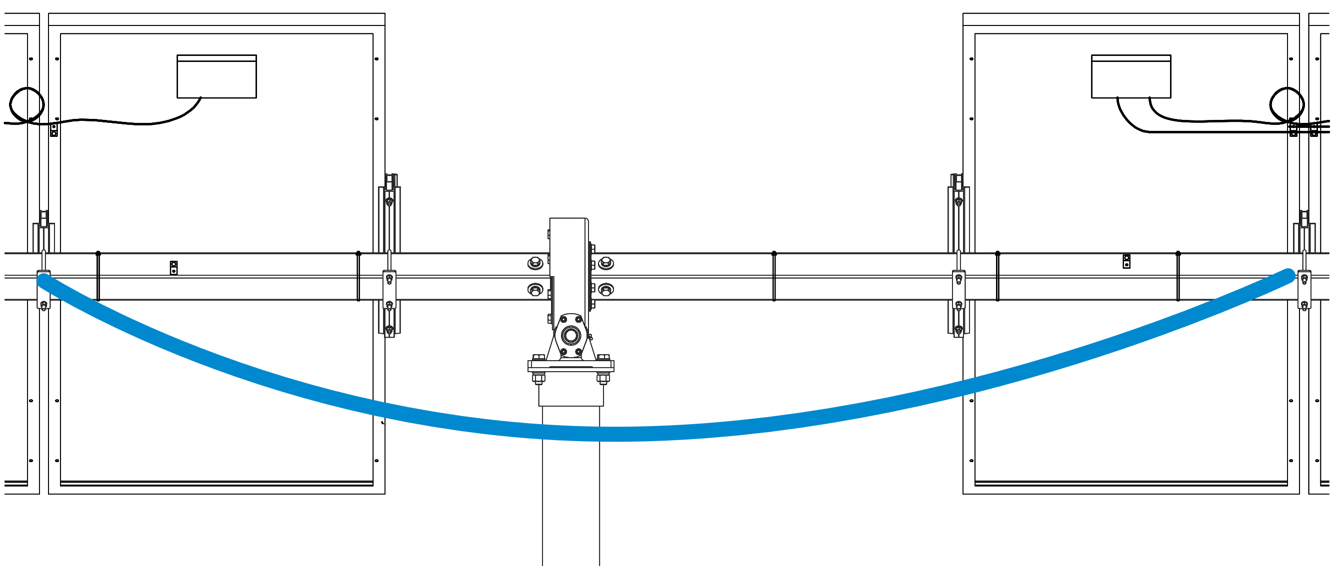
First, an arrest mechanism should be securely fastened to each module adjacent to the gap. This jump is often given extra UV and abrasion protection by using some type of split loom or "snake skin" covering. In this case, the arresting mechanism should securely hold both the wire bundle and the protective covering. Care should be taken to keep water from entering the conduit, or drainage should be provided.

The bundle will then arc down below the gear box and must be held in place on the post. This is often accomplished using a P-clamp. Best practice is to affix the bundle approximately 6" below the gear box. Slack must be left on each side of the tracker to allow for the tracker's range of motion. Typically, a length of 12" is adequate, but a field test is necessary as conditions change.

Optionally, when a location is subjected to high winds or when more support is required, a torque tube tie between the arrest mechanism and the post support helps reduce potential swing of the looped bundle. This will minimize mechanical resonance issues, not slapping into metal or coming loose along the assembly.

Verify that conduit will not obstruct tracker movement. This may cause damage to the conduit and the modules.

Tracker Row Jumper



KEY:

■ CTPUV | *Part: 904-00357*

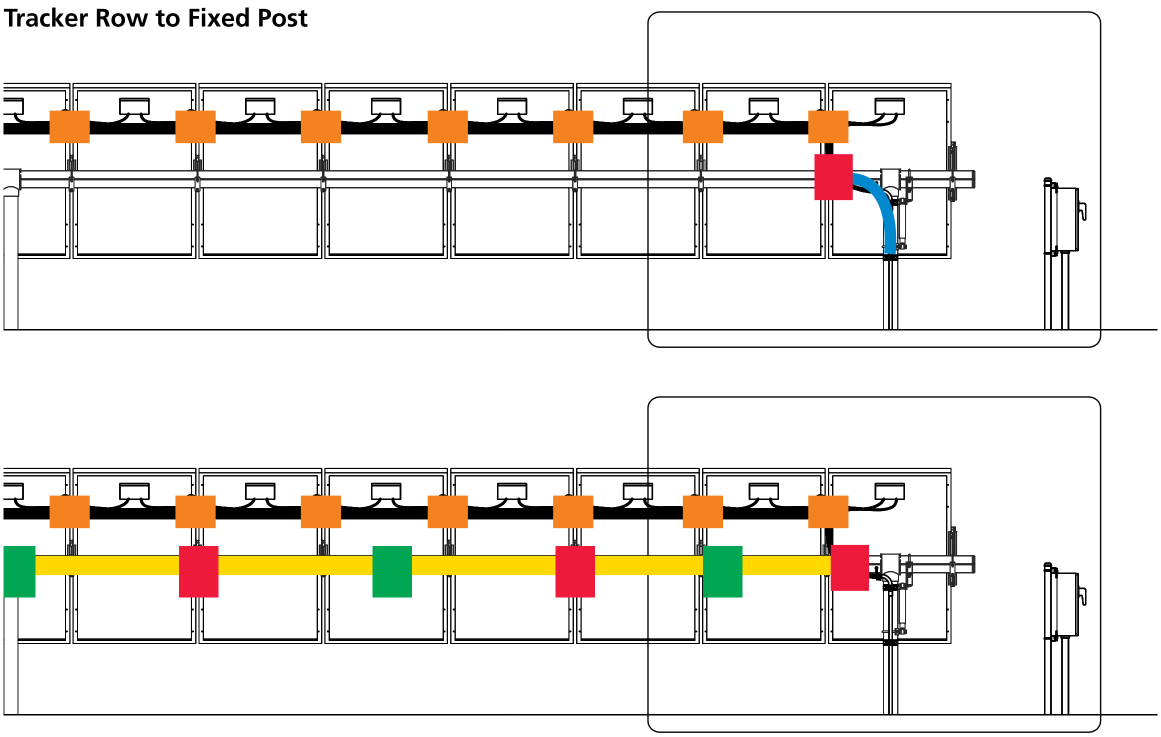
From Tracker Row to Fixed Post

Drip loops – This works well for controlling water infiltration into raceways or boxes. But drip loops are also sometimes used to provide flexibility when wiring transitions from a moving tracker to a stationary pier. This can be an issue over the long term, as PV and USE wiring have not been tested and rated for continuous movement. Over time the insulation can crack, exposing the conductors. Proper wire management with appropriate bend radiuses will minimize wire movement and help combat this issue.

Raceways (Tubing, Conduit, etc.) – This will give you the best protection from damage. The issue is allowing for flexibility while maintaining the integrity of the system and meeting all code requirements. Raceways must be either arranged to drain or protected so water cannot enter them. Water will freeze in colder climates, damaging internal wiring and the raceway. In warmer climates, water can corrode metal and damage wire insulation. According to manufacturer's installation requirements, clamps to attach the raceway are required to be tight enough to prevent slippage, which hinders flexibility. If metal raceways are used, code requires that they be bonded/grounded. This would require bonding jumpers to the metal structure or grounding conductor.

The tubing used on the wiring in this photo would seem to protect the wires from damage. The long, loose run actually encourages damage from lawn mowing equipment and the wind.

Tracker Row to Fixed Post



KEY:

- Ratchet P-Clamp | *Part: 151-01521*
- E-Clip | *Part: 156-00468, 151-00982*
- Home Run Bundle
- Heavy Duty Cable Tie | *Part: 111-01196*

Consideration for extreme movement including tracker movement and heave of fixed structure is necessary with any wire management system. In addition to the movement of the tracker, variations in temperature, seismic activity and water erosion can all lead to movement of the piers and underground conduit. This can be a problem with fixed systems, but becomes an even larger issue with trackers.

Bird perch considerations – Birds will build their nests everywhere. The movement of a tracking system will sometimes slow them down but will not stop them. Always keep this in mind. Bird droppings are corrosive; nests hold in moisture, encouraging rust; and the additional weight can harm wiring and wire management.

This conduit was damaged when the tracker went to the far east position every morning. The conduit also penetrated the module backing and cracked the glass.

Bifacial Modules With Split J Boxes

One significant design change over the last year can be found along the torque tube, where installers are supporting lead wires on bifacial modules with and without split J boxes. This greatly affects how wire management is accomplished on the jobsite. As bifacial modules come to market, it's important to have a flexible strategy and partners that offer a variety of solutions to fit those demands.

Bifacial Modules

Let's start with bifacial modules – the new trend in the utility scale solar market. Bifacial modules bring increased production, which helps enhance profitability while minimally impacting the physical layout of the solar plant itself. These modules bring a new concern for electrical designers - the need to minimize shading on the backside of the module. With bifacial modules, the opportunity to increase production is through allowing more indirect sunlight to hit the reverse side of the solar module. An estimated 20 percent of the light that hits the ground is reflected back at the rear side of a solar module. With snow, it could be as high as 80 percent. Some developers are even installing rocks or brighter colored ground covering to increase reflection. Anything done to change the reflectivity to the back side of the module, changes the discussion around the wire management. Added reflectivity increases the opportunity for UV degradation. In some cases, a more durable polymer may need to be selected.

This project in Oregon utilizes a white ground covering to both increase UV radiation to the back of the modules as well to help mitigate growth of weeds and other ground coverings.

In a typical design, the lead wires as well as the home run cables can run perpendicular anywhere across the back of a solar module. With bifacial, the goal is often to run the wires as close to the top or the middle (along the torque tube) as possible. This presents a challenge, since it requires multiple attachment methods and a variety of wire management parts. Typical module frame attachment methods are often impossible due to infrastructure from the Module Interface Bracket or short module lead wire lengths. Attaching to the torque tube is often one of the few viable options. A round torque tube is approximately 4" in diameter. Doing the math, the circumference is calculated ϖ x diameter, which gives us 12.56", while a 4x4 square torque tube has a 16" circumference.

The challenges don't stop there. Few suppliers offer solar-appropriate cable ties with a minimum length of 15 inches or longer (HellermannTyton does offer Solar Ties up to 30 inches long in a variety of engineered polymers and tensile strengths). In addition, racking manufacturers are particular about allowing penetrations in the torque tubes. Fir tree mounts, clips and arrowheads may make for low cost and extremely durable wire management mounts, but they are often eliminated when routing along torque tubes due to manufacturers warranty provisions.

Another complication is movement. PV wire, metal torque tubes and modules thermocycle differently, causing them to expand or contract independently of one another. Ties that are cinched down too tight can lead to wire damage, wire connector issues or failures at the junction box. Successful wire management along the torque tube is attainable as long as the chosen strategy includes thoughtful consideration for issues such as a slack allowance for thermal cycling versus simply placing a cable tie every two feet while avoiding pinch points and planning for movement of wires.

One last concern: routing around bearings. This is one of the most hazardous areas along the torque tube for wires, as pinching can lead to disastrous results. And, it's hard to avoid. You need to leave enough wire available to allow for thermocycling, but not so much that it requires bundling the excess wire around these pinch points. Routing cable up along the module edge is a good option, as well as using edge clips around module interface brackets (MIBs) could be a nice option as well, considering the factors discussed earlier.

Longer ties are required for dressing wires along the torque tube. Care needs to be taken to make sure that proper materials are specified due to the high temperatures the torque tube can experience. Seen in this photo is the HellermannTyton 22 in. "Torque Tube" Solar Tie, part number 111-01196

Routing around hazardous areas is one of the most important considerations. Module interface brackets are specific areas of danger, being areas of pinch points. HellermannTyton Solar Locking Clamp is installed in this photo. Part number 151-02501

Split J Box

Every module is different, but most of today's split J box modules are in the middle of the panel near the torque tube. The location provides a host of challenges including limited space and sharp edges. MIBs are attached close to where the lead wires are coming off of the module. This requires well-planned wire management to avoid those sharp edges – in a confined space.

Many of the split J box modules on the market still have lead wires far longer than needed (for installs in residential or commercial applications), resulting in routing larger bundles than normal. Metal or plastic E-clips, or clamps with fir trees where holes are available, are often the best solutions in these areas. Consult with your wire management manufacturer throughout your design phase and during your golden row setup.

As you can see in the image, the module leads are significantly longer than needed for this application. Careful routing of the excess wires is paramount in this situation due to the lack of attachment points.

Designing a utility scale solar system that utilizes newer technology modules obviously requires many considerations. Bifacial modules or modules with split J boxes provide innovation to an ever-evolving industry. Working with trusted partners and staying up-to-date on these changes can help you avoid added costs during installation and depleting your maintenance budget down the road.

About HellermannTyton

HellermannTyton is a global manufacturer of identification, cable management and connectivity solutions for the commercial data, telecommunications, OEM and industrial markets. HellermannTyton offers an integrated approach to design, operation and delivery to optimize service and solutions for local and global customers. The company's engineered solutions and innovative products are designed and constructed to meet the strictest quality standards while delivering reliable implementation at the lowest cost.

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