PANDUIT®
infrastructure for a connected world

# Finding Balance

## The Role of Balance of System in Delivering More Efficient and Cost-Effective PV Installations

WHITEPAPER

## Introduction

Over the past decade, the story of utility-scale solar has been one of increasing energy efficiency and decreasing costs. But as photovoltaic (PV) technology matures, these gains are seeing diminishing returns.

According to the International Renewable Energy Agency (IRENA) the levelized cost of utility-scale solar energy dropped 82 percent between 2010 and 2019.[1] The lion's share of the decline in the cost of installation (62 percent) was thanks to more efficient, cheaper-to-produce PV panels and inverters.

As the biggest expense, it's no surprise those components offered the biggest opportunity for savings. Tandem and half-cut solar cell technologies, along with bifacial panel design, have increased solar module efficiency. Inverter voltage capacity has increased from 600 V to 1 kV to 1.5 kV over just a few years.

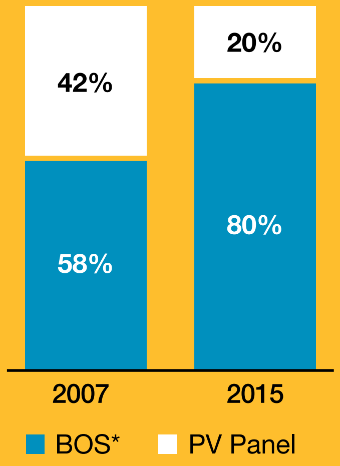
Of course, there have been huge leaps in technology and drops in cost across the entire solar balance of system (BOS), not just in panels and inverters. BOS typically encompasses everything but the solar panel module itself: inverters, racking and trackers, cable management, batteries, and storage, even software and labor costs. Underlying and tying together all of these systems is a solar plant's physical and electrical infrastructure.

Between 2010 and 2019, installation costs dropped 13 percent; racking costs dropped seven percent, and costs for other BOS hardware dropped three percent. With cost savings from PV module and inverter innovations beginning to diminish, the industry is paying increasing attention to BOS and the potential for cost and efficiency savings hidden within.

Going forward, BOS will play a larger role in increasing the performance and minimizing the cost of commercial-scale PV installations.[2]

While there is plenty of room for individual improvements in solar infrastructure, examining BOS as a whole can help uncover opportunities. Physical and electrical infrastructure connects and underpins the entirety of any solar installation and is an ideal lens through which to approach BOS.

Percentage of Installation Costs[3]



*includes inverter

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[1] IRENA, 2020
[2] ibid
[3] Renewable Energy World, 2015

## Balance of System Trends and Implications

### APPLICATION-SPECIFIC PHYSICAL INFRASTRUCTURE

No two solar installations are identical. Working with the right supplier or EPC to get a project's physical and electrical design right from the start will go a long way when estimating project cost. Suppliers and EPCs can help provide an accurate estimate long before construction begins. Such project estimates also help teams meet deadlines once construction has started and sets the groundwork for maintaining optimal performance once a facility is up and running.

One aspect that is particularly important, but often overlooked, is cable management. Intermating different kinds of connectors was determined by one study to be the leading cause of module failure.[4] Running cables over sharp edges, along moving parts, or within reach of animals can also increase the risk of wire damage and electrical shorts.

Using general-use cable clips and ties can result in long-term maintenance issues, especially when exposed to direct sunlight or harsh conditions. Materials designed for desert conditions will not perform as well in coastal areas, and vice versa. Heat and temperature fluctuations can make non-UV-resistant plastic cable clips brittle, while salt can cause metal cable clips to corrode and damage the galvanized edges of PV panels.

These issues can be avoided by specifying solar-specific components that have been tested to withstand outdoor conditions, specifically IEC 61215 standards for PV installations. In solar farms with thousands, if not millions of modules, the cost and labor of continually replacing deteriorating ties adds up.

### Installation Time[5]

Panduit Solar Cable Clip

Traditional Zip Tie

| Panduit Solar Cable Clip | Traditional Zip Tie |
|---|---|
| **11** Seconds | **21** Seconds |

x 3 clips per panel

x 2,900 panels per mW =

| | |
|---|---|
| **26.58 HOURS** labor time per mW with a Panduit solar cable clip | **50.75 HOURS** labor time per mW with a traditional zip tie |

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[4] PV Magazine, 2019

[5] Panduit Japan, 2020

Trackers and bifacial panels present other cable management challenges. Bifacial PV panels can produce up to nine percent more energy than a traditional PV panel.[6] Loosely hung cables can get in the way of this additional capacity. Clips designed specifically for use with bifacial panels keep cabling out of the way, secure along the edge of the panel.

While bifacial technology is relatively new, trackers are not. By 2023, 42 percent of ground mount solar projects are expected to use trackers to maximize panels' exposure to the sun.[7] But tracker support brackets can interfere with typical wire management placement. Routing wires along the torque tube is one solution, especially when the goal is to minimize obstructions on the back of the bifacial panel. However, because torque tubes often lack holes or other mounting options, this can create its own set of problems.

**By partnering with a supplier that has rapid prototyping capabilities, developers can solve installation-specific challenges with custom components.**

## INVERTERS, BATTERIES, AND ELECTRICAL INFRASTRUCTURE

The success of utility-scale solar depends on the ability to provide a consistent, reliable flow of power to the grid. Utility-scale battery storage systems—also known as front-of-the-meter, large-scale or grid-scale battery storage—will be critical to increasing solar power's share of future global energy production.

Battery storage systems fill the gap when demand is high and generation is low, but the opposite is also true. When a solar farm produces more energy than the grid is currently requiring, the wasted energy can be captured and stored for use when its needed.

Utility-scale battery systems can either be AC-coupled or DC-coupled, depending on whether they are coupled with the solar array before or after the PV inverter converts DC solar energy into AC electricity for the grid. The type of battery system chosen has a significant impact on an installation's physical and electrical infrastructure.

Because DC-coupled systems are connected directly to the solar array, they can send more energy directly to the battery system than an AC-coupled system, where some power is lost at the inverter stage. Because they do not need to be installed out in the field next to the inverter, however, AC-coupled batteries can be housed in a central location outside the solar panel array for easier monitoring and maintenance.

Because they are separate from the solar array, there are several other infrastructure advantages to an AC system. Not having to fit in the field means they can use larger racks, and so require fewer HVAC and fire-suppression systems. Because they don't require the bidirectional inverters required by a

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[6] NREL, 2019

[7] Berkeley National Laboratory

DC system, AC systems can be added or upgraded separately from the array itself, whereas retrofitting an array with a DC system requires replacing existing inverters with bidirectional inverters.

Inverter type and capacity has a significant impact on the layout and size of a solar farm. By increasing the amount of energy output per square foot, a 1.5 kV inverter requires less land to produce the same amount of power as a 1 kV inverter. Because it can also accommodate longer strings of panels, it requires less cabling and infrastructure.

Though high voltage inverters may require less physical infrastructure, they require engineers to pay more attention to electrical infrastructure and safety. Personnel working amid thousands of high-voltage rails and large-scale batteries are at considerable risk, so electrical engineers and installers must adhere to best practices and the highest safety standards.

When it comes to grounding and cable management, that means making sure personnel and equipment are protected in the event of a short circuit fault. Although NEC standards require cables be secured, it does not offer best practices for doing so. Cables are often improperly secured with string, cable ties, or cable cleats that are not able to withstand a short circuit fault.

As cable trays become more common in solar farms, design engineers and electrical contractors should ensure the cable cleats they specify are appropriate to the environmental conditions and that they adhere to IEC 61914:2015 to ensure they can withstand a ground fault. More stringent than NEC guidelines, IEC 61914:2015 sets standards for resistance to electromechanical forces, but also outlines requirements for temperature rating, corrosion, UV resistance, and more to ensure cable cleats can withstand harsh construction site conditions.

## DIGITIZATION, MAINTENANCE, AND PLANNING FOR THE FUTURE

In a large-scale solar installation, a single faulty part can take hours or even days to identify, locate, and replace. Damage to a single panel impacts the production of every panel on that string.

Because of this, many solar farms operate with a contingency reserve as high as five percent and overspend on operations and maintenance by as much as eight percent of revenue.[8] Thankfully, greater digitization is increasing solar facilities' capacity to monitor performance. Real-time performance data can help identify degradation and predict faults before they occur. Switching from scheduled to predictive maintenance helps minimize downtime, labor costs, and the spare parts inventory required.

Because the majority of solar farms have been operating for less than a decade, digitization is also helping the industry overall by providing insights that will accelerate the learning curve of applying new technology. Analyzing

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[8] GE, 2017

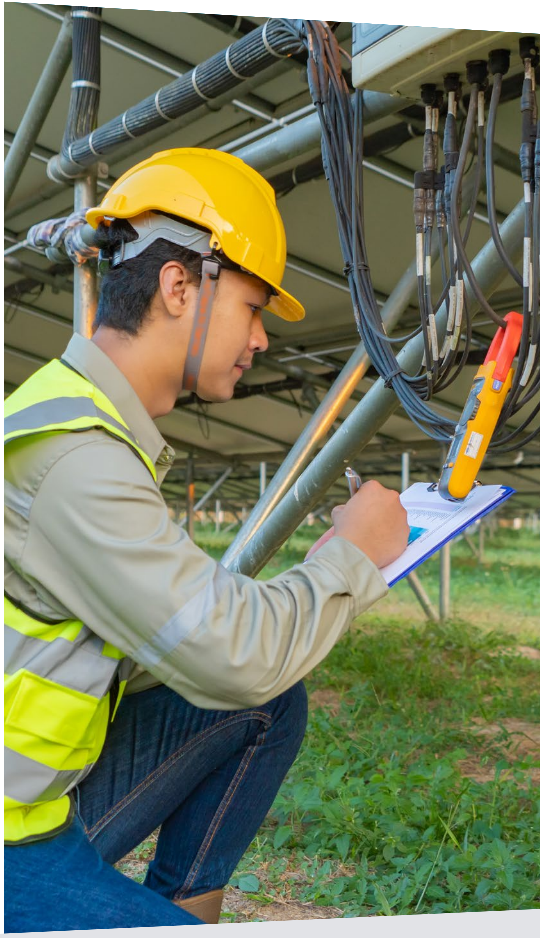
monitoring data can provide a more accurate prediction of future performance, lowering the perceived risk of investing in solar and reducing financing costs across the industry.

Globally, the cost of producing solar power is declining quicker than the costs of both traditional generation and wind power. IRENA estimates that by 2025, average PV electricity costs could decrease as much as 59 percent, compared to decreases of 35 percent and 26 percent for offshore and onshore wind power, respectively.[9] Thanks to these continued improvements, solar power's estimated share of global installed capacity is expected to reach 32 percent in 2040.[10]

## The Physical Infrastructure Powering Today and Tomorrow

As the solar industry has grown, Panduit's physical infrastructure expertise has evolved to play a vital role in renewable energy production facilities around the globe. Over the last decade, Panduit has been leading the way, partnering with EPCs and solar installers on PV installations totaling more than 5GW of capacity.

By lowering installation costs, extending the useful life of an installation, and increasing overall efficiency, Panduit's solar-specific BOS solutions benefit the entire solar energy industry by making solar power more cost-effective overall.



Our combination of engineering and manufacturing expertise means our full portfolio of renewable energy solutions is both broad and deep, able to cover up to 75 percent of a PV electrical installation BOS. Because our solutions have been tested in harsh outdoor conditions—including high wind, high vibration, intense UV exposure, extreme temperatures, and corrosive atmospheres—we are able to recommend and provide products made of the right material, no matter the application or environment.

Our dedicated capital projects team supports projects from beginning to end, from estimating all the way to commissioning. This includes designing and engineering custom prototypes that can be taken into the field and tested in your specific application.

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[9] IRENA, 2017

[10] GE, 2017

Since 1955, Panduit's culture of curiosity and passion for problem solving have enabled more meaningful connections between companies' business goals and their marketplace success. Panduit creates leading-edge physical, electrical, and network infrastructure solutions for enterprise-wide environments, from the data center to the telecom room, from the desktop to the plant floor. Headquartered in Tinley Park, IL, USA and operating in 112 global locations, Panduit's proven reputation for quality and technology leadership, coupled with a robust partner ecosystem, help support, sustain, and empower business growth in a connected world.

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**Visit us at www.panduit.com**

**Contact Panduit North America Customer Service by email: cs@panduit.com**
**or by phone: 800.777.3300**

PANDUIT US/CANADA
Phone: 800.777.3300

PANDUIT EUROPE LTD.
London, UK
cs-emea@panduit.com
Phone: 44.20.8601.7200

PANDUIT SINGAPORE PTE. LTD.
Republic of Singapore
cs-ap@panduit.com
Phone: 65.6305.7575

PANDUIT JAPAN
Tokyo, Japan
cs-japan@panduit.com
Phone: 81.3.6863.6000

PANDUIT LATIN AMERICA
Guadalajara, Mexico
cs-la@panduit.com
Phone: 52.33.3777.6000

PANDUIT AUSTRALIA PTY. LTD.
Victoria, Australia
cs-aus@panduit.com
Phone: 61.3.9794.9020

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