Aerial Spacer Cable for Utility-Scale Solar Energy Sites

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Introduction

Across all electric power generation technologies, utilities worldwide seek to optimize the level of service and reliability of their electric power delivery. One successful practice, in use on all seven continents for over 72 years, is the Aerial Spacer Cable System. "Spacer cable," as it is more commonly referred to, has been demonstrated to improve reliability and quality of service, while driving down operations & maintenance costs. This paper will focus on the application and benefits of using Aerial Spacer Cable Systems for collection systems in utility-scale solar energy facilities.

Background

Utility-scale solar power is relatively new to the electric utility industry. In 1982, the first solar farm was built in Hesperia, California and produced 1 MW. In 1984 a 5.2 MW solar facility was built in Carrizo Plain outside San Luis Obispo California. Solar energy really took off in the first decade of this century, with large scale facilities (150 MW – 550 MW) being built mostly throughout the western United States. At the end of 2023, there were 179 GW of installed solar photovoltaics (utility plus rooftop) in the US, which accounted for 4.7% of the total generation domestically. The U.S. Dept. of Energy released a report in 2021 predicting that by 2035, solar energy could supply 40% of the domestic energy demand, and by 2050, as much as 45%. The challenge for renewable energy proponents and power planners is how to properly design collection systems for these mostly geographically remote solar production facilities and bring that power back to population centers.

Aerial Covered Conductor – Spacer Cable and Tree Wire Systems

Spacer Cable Systems consist of three heavily covered, but unshielded, phase conductors. The conductors are usually AAC when in a spacer configuration, since there is no tension on the phase conductors, but are usually ACSR or AAAC when installed in a self-supported or "Tree Wire" configuration.

In Spacer Cable construction, the phase conductors are attached to a messenger by spacers, installed every 30 ft. (10m.) along the messenger. The messenger is a high strength, alumoweld (AW) or alumoweld-aluminum (AWA) conductor which has several functions. The first is that the messenger is the mechanical strength member, holding the phase conductors up. The messenger can also be used as a system neutral, is a lightning shield, and provides a mechanical protection function by protecting the phase conductors from any items (leaves, branches, trees) which can fall onto the bundle from above. The spacers are made of High Density Polyethylene (HDPE), as are the pin or line post insulators used on the angles, to ensure dielectric compatibility with the phase conductors.

Tree Wire systems, on the other hand, look more like bare wire construction. They utilize the same 3-layer covered conductor design, but the phase conductors are usually either ACSR or AAAC (since Tree Wire systems are self-supported and the phase conductors are fully tensioned). Tree Wire systems are strung in an open wire configuration on crossarms with polyethylene insulators. The photo below on the left shows a Spacer Cable system, while the photo on the right shows a Tree Wire configuration.

Solar farm collection systems do not normally employ Tree Wire for their collection systems, as there are limitations to its compactness, especially when compared to Spacer Cable. And, while Tree Wire performs well in high wind conditions (impervious to conductor clashing), it does not lend itself well to multiple circuit construction.

Impetus for Spacer Cable at Solar Facilities

While small solar projects (defined by capacity of 1 MW or less) currently account for the vast majority of installations (>90%), they make up only one-third of the installed solar capacity nationwide. Small solar sites can be connected directly to the grid at medium voltages. Cable sizing for small solar facilities is relatively trivial as full loads are under 20A at 15 kV and under 50A at 34.5 kV.

Utility-scale solar facilities present more challenges by far. The utility-scaled solar facilities built in the last decade were in the 200 MW – 550 MW range, and projects on the books for 2024 and beyond are even larger, ranging from 200 MW to 2,000 MW. Siting blocks of panels, strings (lines from individual power blocks to the collection circuit), and collectors (34.5 kV lines which aggregate power from individual strings to transport back to the substation) becomes more complicated. This is because as the sites grow in scale, solar panels for MW production begin to compete for space with the strings and collectors.

When/Where Spacer Cable is Viable for Solar Facilities

There are a number of factors which determine whether underground cable, bare wire, or Spacer Cable is best suited for the collection system of a large-scale solar facility. Those factors are reviewed below.

Topography

As it turns out, most large-scale solar facilities are on predominantly flat land, with minimal to non-existent rock formations or other nonconformities which might require blasting to create a Right-of-Way (ROW). So there are relatively few technical obstacles to installing either bare wire or underground cable for collection circuits.

Conductor Clashing

The phenomenon of conductor clashing, or "conductor slap" as it is sometimes called, is usually due to conductors swinging wildly in high winds resulting in unintended contact. When bare phase conductors do touch one another, the result is vaporization of aluminum, ejection of superheated metal particles, a possible wildfire ignition scenario, and an extended outage. Unfortunately, the outage is not confined to a single string, but rather to all the strings connected to the affected collection circuit. A collection circuit will have numerous strings and carry up to 30/40/50 MW. The conductor clashing incident then leaves a major block of generation off-line for the time it takes to locate and repair the fault, which can be days or even weeks, depending on the location and repair requirements.

When the collection circuit is constructed with Spacer Cable, the conductors themselves are attached to spacers every 30 feet in close spacing (approximately 12 inches) and are thus held in place and unable to contact one another. However, should a wind event take place which results in conductor-to-conductor contact, there will be no damage. The covered conductor's insulation will limit the leakage current to a fraction of a milliamp and avoid a flashover and any attendant damage that would otherwise be experienced with a bare wire line.

Solar ranch downtime is costly as large blocks of power may be off-line for an extended period which severely cuts into MW production and revenue. Spacer Cable collection circuits prevent outages due to conductor clashing.

Improved Voltage Regulation

An indirect benefit of Spacer Cable is its intrinsic ability to improve voltage regulation. While spacing between phase conductors of a bare wire system might be six or eight feet, phase to phase spacing of Spacer Cable phase conductors is closer to one foot. As the phase conductors come closer together, the mutual inductance of the system is vastly reduced, with the result that the total system impedance is 15% or so lower (than an equivalent bare wire or Tree Wire configuration). This means there will be a better end-of-line voltage, or that a line 15% longer can be built with the same conductor size. Alternatively, depending on losses, a smaller conductor size may be selected for the collection circuit, effectively saving significantly on aluminum conductor purchases for the facility.

Underground (UG) Conductor De-Rating Issues

The standard practice for connecting solar power blocks to the substation at solar farms up until around 2010 was to use UG cable. A challenging characteristic of solar farms is that they are often situated in extremely hot desert climates. As such, there are two factors which contribute to cable ampacity de-rating. The first is high soil resistivity. Soil in desert areas tends to be dry with high thermal resistivity. It conducts heat very poorly and essentially traps heat. The excess heat entrapped reduces the current carrying capacity of the cable.

The second factor affecting ampacity de-rating is the ambient temperature. Design criteria require consideration of a fifty-year high ambient temperature for cable operation. If the ambient temperature requirement is very high (i.e., some designs require consideration of 125°F five year high ambient), the UG cable ampacity is similarly severely reduced. Starting with an environment with an elevated ambient temperature and burying the cable in soil which traps heat leads to significant de-rating. For example, an UG cable with a rated ampacity of 1,000 A in an environment with high ambient temperature and high soil resistivity will be de-rated to less than half of that, thus requiring paralleling of phase conductors for the UG option in order to attain sufficient ampacity. The following photo demonstrates this phenomenon. A Spacer Cable system utilizing 1033 kcmil, 34.5 kV covered conductors, transitioning to UG at a riser requires two 1000 MCM UG cables per phase to match the ampacity of a single aerial Spacer Cable. The cost differential between the two options is enormous.

Multiple Circuit Construction

Utility-scale solar farms, are, by definition, multiple circuit facilities. Building collection circuits with bare wire limits the number of circuits per pole to two. Some sites use three bare wire circuits per pole, but it is cumbersome and requires more work and caution for maintenance. With Spacer Cable, there are no such restrictions. Systems have been built with as many as nine circuits per pole line. While this increases financial outlays for poles, the overall savings is significant. The photo below shows a pole line with nine collection circuits, each carrying 50 MW.

OPMW – Optical Messenger Wire

Fiber optics are used in solar farms for monitoring and controlling. Not only are solar panels monitored for proper operation, but a wide array of automated fail-safes are also included in order to head off potential problems. A major benefit of Spacer Cable is that the fibers can be put into the messenger, thereby eliminating the need for a pole which is five feet taller. This saves on pole cost and minimizes any tower shading (reduction of sunlight reaching the solar panels which affects MW production) by taller poles or towers which would otherwise cast shadows.

The photo below left shows an installation whereby the fiber is strung as ADSS above the power space on the pole. This creates the need for a pole which is at least five feet taller. The photo below right shows where the fiber has been put into the messenger. This alleviates the need for a taller pole or a second messenger (ADSS self-support), makes for a lower profile installation, and leads to project cost reduction.

Space Considerations

In joint use ROWs, UG cables are usually placed six feet apart. For a facility with, say, eleven collection circuits, this requires 72 feet of ROW. Utilizing Spacer Cable, the ROW required for a single pole line is less than 1/3rd of that, essentially freeing up real estate for more panels and more MW production.

Environmental Stewardship

The Avian Power Line Interaction Committee (APLIC) requires steps to be taken to avoid avian risks arising from contacts between power lines and birds, the ultimate goal of which is to avert avian mortality. Spacer Cable systems, being completely covered, satisfy the goal of APLIC compliance.

Entering the Substation

Utility-scale solar farms pump their MW production into substations ideally situated next to high voltage lines, so that the power may be sent back to urban load centers. Standard practice in the past was to bring the lines to a pole just outside the substation fence, then transition to UG cable, run the lines under the fence and then up to the substation bus. These connections are unwieldy, costly (cabling, terminations, cabinets, switchgear, etc.), and labor intensive. Using Spacer Cable provides the opportunity to deadend the circuit on a pole outside the substation fence, then run a slack span from the last pole directly to the substation bus.

The photo above top shows circuits turning an angle off the last pole outside the substation fence, then running as a slack span (no messenger) into the substation.
The photo above bottom shows the phase conductors deadending on the substation bus.

Additional Decision Criteria Value for Choosing Bare Wire, UG Cable or Spacer Cable

1. **Facility Layout** – How are the power blocks and collection circuits located physically with respect to the substation location? If the power blocks surround the substation the collection circuits will each have their own ROW and bare wire or UG cable may be viable. If the power blocks are all in one location and all collection circuits share a common ROW, then Spacer Cable is the economic choice.

2. **Collection Circuit Length** – Are the circuits short, medium length or long? The longer the collection circuits the more valuable is the Spacer Cable configuration to reducing the voltage drop. On long, voltage limited collection circuits, Spacer Cable will allow cable size reduction compared to that of bare wire, and result in savings. In the case of UG collection circuits, while they will not necessarily be voltage limited, they will be thermally limited and their ampacity de-rating will favor Spacer Cable.

3. **Facility Size** – At some MW size (perhaps greater than 150-200 MW), these sites are big enough, with numerous collection circuits, that Spacer Cable is significantly lower in cost than other options. Below this threshold, collection circuit viability will depend on other factors.

4. **Site Density** – Solar facilities are by definition dense, utilizing every available square foot of real estate for panel placement and MW production. For multiple circuit construction, space constraints are even greater, favoring Spacer Cable. When we start adding battery storage, it is even more difficult to site additional power lines unforeseen when the original site was planned. The addition of battery storage is the newest paradigm shift at solar sites, exacerbating the crowdedness of the sites and begging for space-saving solutions like Spacer Cable systems.

Summary and Conclusions

Experience has shown that Spacer Cable Systems are a technically viable and economic choice for the collection systems of many utility-scale solar farm facilities. Savings can be attributed to improvements in reliability and availability (storm hardening and elimination of conductor clashing), ease of multiple circuit construction, improvements in power quality, increases in safety, and cost reductions made possible by utilizing design strategies afforded by this technology.

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April 2024