

FIMER



Whitepaper

**Beyond the Warranty: Understanding
Lifecycle Risk in Utility-Scale Solar
Projects**



Executive Summary

Selecting the wrong power conversion technology can create significant long-term financial risk for a utility-scale solar project.

Most utility-scale solar financial models include a planned mid-life refurbishment or equipment replacement event after the original warranty expires. This investment is intended to maintain plant availability while avoiding the increasing failure rates associated with aging equipment.

However, this approach is only viable if the original manufacturer continues to support the product with spare parts, technical service, and repair capabilities. When manufacturer support is unavailable, owners and operators may face escalating maintenance costs, reduced plant availability, and unplanned capital expenditures.

Industry trends over the past fifteen years demonstrate that many inverter manufacturers have merged, exited the market, or ceased operations, leaving owners with unsupported products well before the end of the project's financial life.



Background

Between 2009 and 2025, more than 19 companies supplied inverters to the U.S. utility-scale solar market. During that period:

- 5 companies restructured, merged, or consolidated
- 2 companies went out of business
- 6 companies exited the solar inverter market segment

The technology landscape also changed dramatically over the same period:

- DC system voltages increased from 600 V to 1,000 V and then to 1,500 V, with the industry now evaluating 2,000 V architectures.
- Transformer-based inverters were largely replaced by transformerless designs.
- Central inverter ratings grew from approximately 250 kW to more than 4 MW.
- String inverter ratings increased from approximately 20 kW to more than 300 kW.
- Many modern string inverters became modular, field-replaceable products rather than repairable platforms.
- Central inverter systems evolved from field-assembled power conversion systems into factory-integrated skid solutions incorporating equipment from multiple OEMs.
- AC output voltages increased alongside DC voltage growth, progressing from 208 V to 380–420 V, then to 600–690 VAC, and in some applications to 800 VAC.
- Grid-interconnection requirements changed significantly under IEEE 1547, moving from basic anti-islanding functionality to advanced grid-support capabilities that can be coordinated through utility communications and control systems.



Impacts

The combination of manufacturer consolidation and rapid technology evolution has resulted in near-complete obsolescence of inverter platforms sold between 2009 and 2015. This raises an important question: how can equipment become obsolete within 10–15 years when utility-scale solar projects are commonly financed for 25 years or more?

The answer lies in two overlapping trends:

Industry Consolidation

As the solar industry matured, manufacturers acquired competitors to gain market share, intellectual property, manufacturing capacity, and installed base. After consolidation, manufacturers typically standardized around a limited number of product platforms, which often led to the discontinuation of legacy inverter lines and reduced availability of parts and service support.

Market Competition and Technology Turnover

Intense price competition, changing grid requirements, and rapid improvements in inverter efficiency and power density caused several manufacturers to exit the market or discontinue older product families. Even when a company remained in business, its newer platforms were frequently incompatible with earlier equipment.

The result is that many utility-scale projects now operate inverter systems that are no longer manufactured, no longer supported, or no longer aligned with current grid-interconnection standards.



Impacts to the market, from a 2015 and 2025 snapshot in market leaders:

Reference Company	Rank 2015	Market Share 2015	Rank 2025	Market Share 2025
A	1	24%	2	9%
B	2	16%	Consolidated new Product	0%
C	3	10%	3	7%
D	4	8%	Exit market	0%
E	5	7%	Out of Business	0%
F	6	6%	4	5%
G	7	5%	Out of Business	0%
H	8	5%	1	22%
I	9	3%	7	1%
J	10	3%	6	3%

Table: Utility market leaders by year



Things to Consider

Unlike many mature electrical products, solar inverters do not have a universal form-and-fit standard. The industry is standardized primarily around function through requirements such as IEEE 1547 and UL 1741, which define grid-interconnection and safety performance.

However, these standards continue to evolve. For example, an inverter certified to IEEE 1547 requirements that were common in 2015 may not fully satisfy utility or regulatory expectations in a 2026 installation without additional upgrades or replacement.

Every revision of UL 1741 introduces new safety, interoperability, cybersecurity, or grid-support requirements. As utilities increasingly require compliance with the latest editions, legacy inverter platforms may become difficult—or impossible—to certify for new projects or replacement installations.

How the UL has evolved

- UL 1741 (1999) – Early edition covering basic safety and performance requirements for inverters and related equipment
- UL 1741 (2010) – Major update, likely incorporating changes from IEEE 1547 and expanding scope to include more DER equipment
- UL 1741 Ed. 2 – 2010 – Second edition, building on the 2010 base
- UL 1741 Ed. 3 – 2021 – Published September 28, 2021, with major updates including enhanced grid-support function testing, alignment with IEEE 1547-2018/1547.1, and new requirements for cybersecurity and functional safety
- UL 1741 Ed. 3 +R:23Oct2024 – October 23, 2024 revision added requirements to reference UL 3141 (Outline of Investigation for Power Control Systems) and updated marking signal words
- UL 1741 Ed. 3 +R:22Apr2025 – April 22, 2025 revision corrected marking signal words to match hazard severity and added references to DER cybersecurity standards
- UL 1741 Ed. 3 +R:21May2026 – May 21, 2026 redline revision, the latest published



To understand the challenge, consider the Edison-base light bulb:

- Bulbs are available in different shapes, wattages, color temperatures, and technologies (incandescent, fluorescent, LED).
- Despite these differences, most bulbs can still fit and operate in the same socket because the physical interface remains standardized.
- Homeowners typically do not need to redesign their electrical systems when lighting technology improves.

Utility-scale inverters have no equivalent mechanical standard. While performance standards exist, each manufacturer defines its own physical architecture, cable routing, cooling system, enclosure dimensions, and service interface. The following characteristics are critical:

- Power rating (kW/MW, kVA, and temperature derating)
- DC operating voltage
- AC output voltage and grid configuration
- Physical form factor (size, weight, and footprint)
- Cable entry and wire-management design
- Integrated protection devices such as fuses, breakers, disconnects, and switches

The closer these characteristics are between successive product generations, the easier it becomes to refurbish, upgrade, or replace equipment without major modifications to the balance-of-system infrastructure.



How Things Fail

Inverters, comprised of both mechanical and electrical systems, are designed for the environments in which they are operated, and are designed to be maintained.

Utility-scale inverters are designed as maintainable assets rather than disposable equipment. Their long-term reliability depends on periodic preventive maintenance, timely replacement of wear components, and continued availability of qualified spare parts.

The frequency of failures is measured in MTBF (mean time between failures).

$$\text{MTBF} = \text{Operating Hours} / \# \text{ of Failures}$$

The time it takes to repair (including actual labor plus time to source components) is the MTTR (Mean time to repair).

The system performance is typically measured in Uptime or Availability. Availability is the total hours of service experiences divided by the number of hours of service targeted.

$$\text{Availability} = \text{MTBF} / (\text{MTBF} + \text{MTTR})$$

Example:

9 hours MTTR

8751 hours MTBF

$8751 \text{ hours} / 8760 \text{ hours} = 99.9\% \text{ Uptime}$

Reducing MTTR can improve plant availability just as effectively as increasing MTBF. This highlights the importance of maintaining local spare parts inventories and long-term OEM service support.



How Components Fail

Components fail due to several mechanisms. Each can failure mode can be expressed in a bathtub curve, which covers 3 major categories of failure:

1. Infant Mortality:

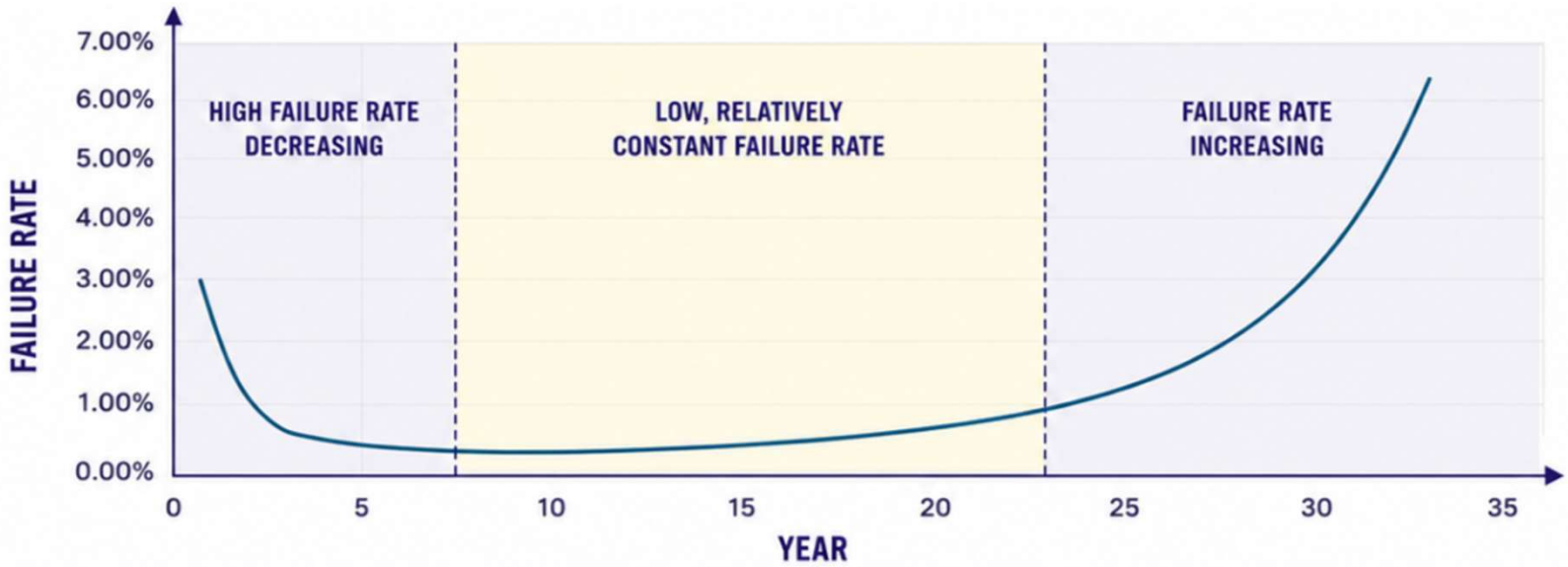
- The first 2 years, typically under Warranty
- Failures characterized as
- Manufacturing defects
- Shipping damage
- Installation errors
- Poor solder joints

2. Useful Life:

- The operational life of the product, typically 20 years
- Failures characterized as
- Random failures
- Lightning
- Grid disturbances
- Human error
- Occasional component defects

3. Wear out region:

- Any time beyond the useful life. Wear-out mechanisms are largely predictable and therefore suitable for planned refurbishment rather than emergency replacement.
- Failures characterized as
- Electrolytic capacitor dry-out
- Fan bearing wear
- Relay contact erosion
- Solder fatigue
- Thermal cycling
- Corrosion
- Connector Oxidation



Graph 1: Component failures by year



Takeaways

The most effective long-term maintenance strategy is to avoid major platform changes whenever possible and instead refurbish the installed platform on a predictable schedule. Planned refurbishment of aging components restores reliability while preserving the existing balance-of-system infrastructure, minimizing capital expenditures and reducing project risk. As we approach the end of product life, which is typically shorter than project lifespans, we are most vulnerable to exponential failure rates and require major planned refurbishment to maintain Availability.

This approach depends on a manufacturer's long-term commitment to:

- Maintain spare-parts availability
- Provide field service and technical support
- Qualify replacement components from multiple sources
- Support the platform throughout the project's operating life

These capabilities represent a critical but often overlooked aspect of lifecycle bankability. While traditional bankability focuses on a manufacturer's financial strength and product certifications at the time of purchase, lifecycle bankability reflects the manufacturer's ability to support the installed platform throughout the full economic life of the asset. Long-term lifecycle support reduces technology obsolescence risk, preserves the value of existing infrastructure, and provides owners with greater confidence that the platform can be maintained economically for decades.

FIMER addresses this challenge through a comprehensive lifecycle support strategy for the PVS980 platform. This strategy includes documented service-life commitments, proactive obsolescence management, multi-source qualification of critical components, global spare-parts logistics, and factory-trained field service capabilities designed to support plant operation through 2051. By reducing lifecycle risk and extending the economic life of installed assets, FIMER helps owners protect long-term project value while maximizing availability and minimizing total cost of ownership.