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Toward Streamlined Permitting and Interconnection of 240 V Plug-In Photovoltaic Appliances

November 2026

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U.S. DEPARTMENT of ENERGY
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Abstract

Plug-in photovoltaic (PV) systems offer a promising pathway to expand access to clean, consumer-deployable solar energy, particularly for renters and other customers who may not be able to install conventional rooftop PV. However, deployment of plug-in PV in the United States remains limited because interconnection, permitting, and code-compliance pathways are often unclear, inconsistent across jurisdictions, and designed primarily for permanently installed distributed energy resources (DERs), rather than mobile or appliance-class products. Key barriers include touch safety, breaker masking, bidirectional ground-fault protection, National Electrical Code (NEC) interpretation, utility interconnection requirements, and Authority Having Jurisdiction (AHJ) permitting practices. This paper reviews the principal U.S. codes, standards, and regulatory issues relevant to plug-in PV interconnection, including NEC provisions, IEEE 1547 interconnection requirements, UL certification pathways, and utility approval processes. It then analyzes the technical, regulatory, and procedural barriers affecting deployment of medium-size 240 V plug-in PV appliances, with emphasis on GismoPower's Mobile Electricity Generating Appliance (MEGA)®, a portable carport with removable wheels that integrates PV panels and an electric vehicle (EV) charger. Building on this analysis, the paper presents a draft permitting guide for deployment of MEGA®. The guide is intended to serve as a technical and policy resource for AHJs, utilities, and deployment stakeholders by outlining a risk-informed framework for reviewing and approving qualifying 240 V plug-in PV appliances, including technical documentation, inspection checklists, and potential notification-only or expedited approval pathways.

1.0 Introduction

Plug-in, or "balcony," solar refers to small photovoltaic (PV) systems that connect to a building's electrical installation through a cord-and-plug connection, typically using a conventional power outlet, as described by the Clean Energy States Alliance [1]. Unlike conventional loads that draw electricity from an outlet, these systems inject electricity into the premises wiring to serve on-site loads. Depending on the system configuration and applicable requirements, surplus generation may also be exported to the utility grid, subject to applicable interconnection, metering, and utility requirements.

Plug-in solar has gained significant traction in Europe, with Germany representing one of the most mature markets. A Southern Alliance for Clean Energy overview reports that Germany had more than one million registered balcony solar systems, collectively representing approximately 700 MW of installed generation capacity [2]. This growth followed a staged evolution of technical and regulatory requirements. German standards established safety and installation requirements for integrating plug-in PV systems into low voltage electrical installations, while VDE-AR-N 4105 specifies technical requirements for the connection and operation of generating units in low-voltage distribution networks. Germany subsequently simplified the framework for small balcony PV systems, including an 800 VA inverter output limit and a streamlined registration process. These measures have helped facilitate deployment while providing utilities with information about installed systems for distribution system planning and network modeling. The rapid growth of balcony PV in Germany, compared with the limited deployment reported in 2018 [3], illustrates the potential importance of clear technical requirements, streamlined registration, and well-defined utility processes in enabling consumer-scale distributed generation.

Outside Germany, plug-in solar is permitted, notified, or otherwise regulated in several European markets. SolarPower Europe reports that an 800 W AC threshold is used in the regulatory frameworks of several countries, including Germany, Austria, Spain, Lithuania, Slovenia, Portugal, Italy, Belgium, and Switzerland, although the applicable requirements differ substantially among jurisdictions. Some countries apply different limits or additional restrictions. For example, France applies a lower power threshold and places restrictions on export, while Sweden has historically taken a more restrictive approach to plug-in operation. Available deployment data remain limited, but several markets report significant or growing adoption. France's distribution system operator, Enedis, reports approximately 34 MW of cumulative PV capacity for systems below 1 kW by the end of 2024; this category is not limited to plug-in systems [4]. In Austria, the annual market for "micro-PV" systems in 2023 and 2024 was reportedly in the 10–15 MW range, with approximately 20,000 systems registered per year [4]. In Lithuania, approximately 350 plug-in PV users had been registered by the distribution system operator following legalization of the technology in early 2023 [4].

U.S. research on simplified PV deployment predates recent balcony-solar policy discussions. Fraunhofer CSE's DOE SunShot project, reported in 2016, investigated residential rooftop PV hardware together with electronic permitting, inspection, and interconnection [5]. This work provides a precedent for coordinating product design and administrative processes, although its rooftop systems differ from the mobile appliances considered here.

Compared with Europe, plug-in PV deployment in the United States remains much more limited. Because plug-in PV systems can inject electricity into a building's electrical installation and, depending on the configuration and applicable rules, may export surplus electricity to the utility grid, their treatment depends on state and local requirements, Authority Having Jurisdiction (AHJ) interpretations, utility interconnection procedures, and applicable National Electrical Code (NEC) and product safety requirements. Consequently, the U.S. regulatory landscape remains fragmented. Many utilities and jurisdictions apply interconnection procedures developed for conventional, permanently installed distributed energy resources (DERs), which may not be well aligned with consumer-deployable, appliance-oriented plug-in systems. Recent U.S. research similarly identifies technical, regulatory, product certification, and utility interconnection barriers to broader deployment of plug-in DERs despite growing interest in the technology and the experience of European markets [6].

Utah is among the first U.S. states to adopt explicit legislation addressing this category of technology. Utah H.B. 340 establishes a framework for portable solar generation devices with up to 1,200 W of backfeed through a standard 120 V outlet, subject to specified safety, anti-islanding, testing, and certification requirements. Following Utah, other states have adopted policies addressing portable or plug-in solar generation, with examples including Maine, Maryland, and Virginia. These examples are not an exhaustive count. Virginia's framework, effective January 1, 2027, establishes requirements for portable solar devices up to 1,200 W and limits certain utility interconnection requirements and fees, while also addressing restrictions that may be imposed by landlords [7]. These state-level actions indicate growing policy interest in simplified pathways for small plug-in PV systems. However, state legislation alone does not establish a uniform technical and regulatory pathway for plug-in PV deployment across the United States.

Federal policy proposals also distinguish small portable systems from the 240 V appliances considered here. H.R. 10851, the *Socket Full of Sunshine Act*, was introduced on October 19, 2026. As introduced, it would add a PURPA standard requiring consideration of measures such as interconnection-agreement exemptions and restrictions on utility-imposed requirements; it would not itself impose those exemptions nationwide. Its definition covers devices with maximum output not exceeding 1,200 W connected through a standard 120 V AC outlet, subject to NEC compliance, certification by UL or an equivalent nationally recognized testing laboratory, and a specified power-control condition.[1] The bill is a legislative proposal, not an authorization for the medium-size 240 V class examined in this report [8].

These challenges become more significant for medium-size 240 V plug-in PV appliances, such as GismoPower's MEGA® (Mobile Electricity Generating Appliance). The MEGA integrates PV generation, power conversion, a cord-and-plug premises connection, and Level 2 EV charging. Configurations have evolved over time. Manufacturer-reported deployments include nine 540 W modules (4.86 kW DC) at Las Vegas and the first Pine Ridge installation, and eight 705 W modules (5.64 kW DC) at a second Pine Ridge installation [9, 10]. GismoPower describes current configurations using eight or

[1] The proposed PURPA definition in Section 2 requires a PCS at output greater than or equal to 400 W, whereas the bill-wide definition in Section 6 uses greater than 400 W. The difference concerns devices rated exactly 400 W.

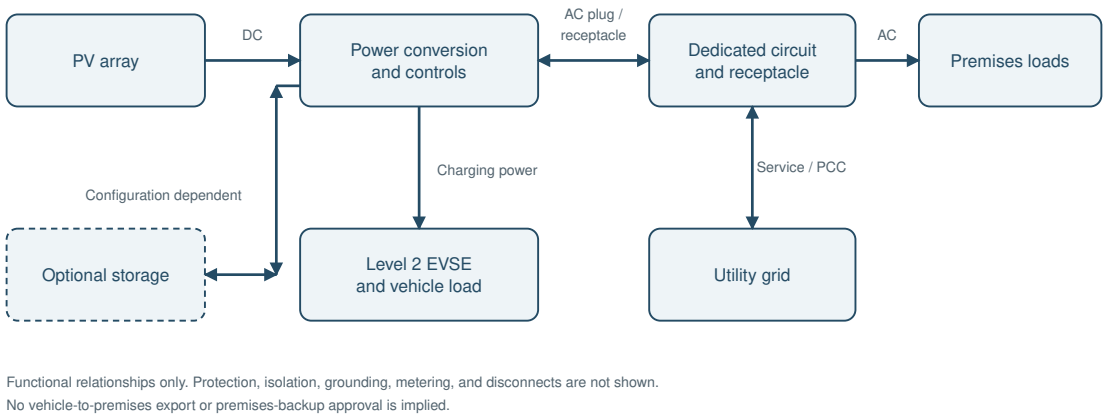


Figure 1: Conceptual functional overview of a MEGA®-type system, informed by [12, 9]. Optional storage is configuration dependent. Protection and interconnection equipment are omitted for clarity; the figure does not establish an approved wiring arrangement.

nine 710 W bifacial modules (5.68 or 6.39 kW DC), a grid-forming hybrid inverter, and optional scalable battery storage offered in 16 or 32 kWh configurations [11]. These are manufacturer-reported specifications rather than independently verified performance or certification findings. DC module nameplate capacity, inverter AC output, and branch-circuit rating are distinct quantities and should be documented separately for each deployment. Figure 1 illustrates the principal functions without specifying a particular inverter manufacturer.

The MEGA is materially different from small 120 V plug-in PV products with relatively low power ratings. Its 240 V connection, dedicated-circuit architecture, higher generation capacity, mobility, and integrated EV-charging functionality introduce additional electrical, interconnection, and permitting considerations. Consequently, state policies developed for small plug-in PV products should be viewed as policy precedents rather than as direct authorization for MEGA deployment.

This paper combines a review of published requirements with preliminary stakeholder input and proposes a framework for future implementation. It does not certify a specific MEGA configuration, validate the proposed pathways through field deployment, or establish site-specific distribution system compatibility.

2.0 Stakeholder Survey Findings

A brief stakeholder survey was distributed to utility and regulatory contacts to identify interconnection and permitting concerns for MEGA®-type systems. Three responses were received: one from a regulatory stakeholder and two from utility stakeholders. Because the response set is limited, the findings should be interpreted as preliminary stakeholder input rather than a statistically representative survey of U.S. interconnection practices. Respondents indicated that distributed energy resources (DERs) interconnection is generally governed by utility-specific interconnection requirements or state interconnection rules. When asked how a product such as MEGA® would be classified, one respondent indicated that classification would be determined case by case, while two respondents classified it as a DER. Respondents also identified certification and listing as key requirements for approval. One respondent identified UL or IEC certification, another identified IEC certification, and another referenced state rules governing the electric interconnection of distributed generation facilities. These responses suggest that utilities and AHJs are likely to require a clear certification pathway before approving broader deployment. The primary barriers identified by respondents included equipment certification, device control, parallel operation with the utility versus backup-only operation, classification uncertainty, connector and backfeed safety, de-energization behavior, protection requirements, and grid impacts such as minimum load conditions, high voltage caused by excess export, and harmonics. Respondents recommended several steps to accelerate approval, including certification or listing relevant to utility requirements, establishment of a clear and standardized compliance pathway that AHJs and utilities can rely on, and submission of interconnection requests through existing interconnection rules where required. One respondent emphasized that the most helpful guidance would be to reduce ambiguity and anchor the device to familiar standards and code pathways already trusted by AHJs and utilities. Specifically, the respondent suggested aligning inverter-based DER protection with UL 1741 SB and IEEE 1547-2018, while also considering UL 2200 in jurisdictions that default to generator-type requirements for mobile or hybrid devices.

Table 1 summarizes the three stakeholder responses. The table reports stakeholder views and should not be interpreted as a substitute for the applicable utility tariff, interconnection manual, state rule, or AHJ determination.

Table 1: Stakeholder Interconnection Matrix

Topic	Stakeholder responses	Implication for MEGA®	Additional information that may be needed
Governing requirements	Utility-specific interconnection requirements or state distributed generation interconnection rules were identified as controlling.	MEGA® will generally remain subject to the serving utility's process unless an applicable exemption or alternative pathway has been adopted.	Applicable tariff, application form, technical screen, fee, review timeline, and agreement requirements for each target utility.

Table 1: Stakeholder Interconnection Matrix, continued

Topic	Stakeholder responses	Implication for MEGA®	Additional information that may be needed
Classification	Two respondents classified MEGA® as a DER; one indicated that classification would be determined case by case.	The three responses did not establish a common classification as an appliance, generator, EV charging product, mobile DER, or conventional interconnected DER.	Written classification from each utility and AHJ, including treatment of grid-parallel and backup-only modes.
Certification	Responses referenced UL or IEC certification and state rules for interconnection of distributed generation.	A clear product- and function-specific certification package is likely to be required before routine approval.	Specific standard, edition, Nationally Recognized Testing Laboratory (NRTL) requirement, applicability to the complete system, and acceptance of equivalent certifications.
Operating mode	Stakeholders distinguished parallel utility operation from backup-only operation and raised concerns regarding device control.	The application must clearly identify whether the system is non-export, limited-export, export-capable, or backup-only.	Operating diagrams, control settings, commissioning records, and fail-safe response.
Connector and backfeed safety	Connector safety, de-energization, and backfeed protection were identified as barriers.	Inverter unintentional islanding certification alone may not demonstrate touch safety or suitability of the plug-and-receptacle interface.	UL 3700 or equivalent evaluation, connector information, and disconnecting-means determination.
Protection	Respondents identified uncertainty regarding protection and certification expectations.	Dedicated circuit, GFCI, overcurrent, grounding, and source/load coordination requirements should be documented.	Bidirectional GFCI availability, overcurrent-device suitability, circuit rating, and applicable NEC interpretation.
Distribution impacts	Concerns included system minimum load, voltage rise from excess export, and harmonics.	Even if customer-side safety issues are resolved, the utility may require export controls or distribution-system screening.	Export scenarios, IEEE 1547/UL 1741 documentation, transformer loading, voltage, and harmonic studies.

Table 1: Stakeholder Interconnection Matrix, continued

Topic	Stakeholder responses	Implication for MEGA®	Additional information that may be needed
Approval accelerators	Respondents recommended relevant certification, a standardized compliance pathway, and use of existing interconnection procedures where required.	A standardized data package may reduce review time, but existing interconnection processes remain the default until an alternative is formally adopted.	Utility willingness to accept an expedited screen, pilot, or notification-based process.

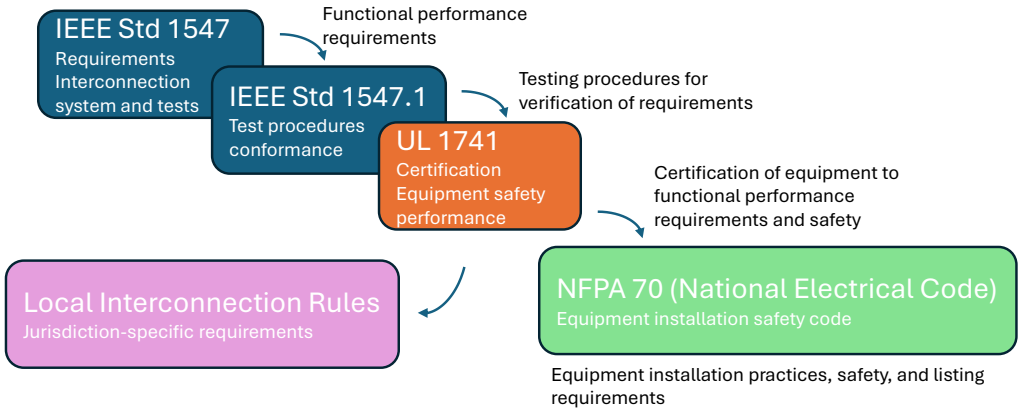


Figure 2: Implementation of IEEE 1547 and related standards and requirements in the United States [13].

3.0 Technical Standards and Interconnection Requirements

Deployment of plug-in PV systems in the United States involves several overlapping technical, product-safety, installation, and utility-interconnection frameworks. For conventional grid-connected DERs, IEEE 1547 establishes technical requirements for interconnection and interoperability, IEEE 1547.1 establishes conformance test procedures, UL 1741 provides applicable product safety and certification requirements for covered inverter and interconnection equipment, and the National Electrical Code (NEC) and local AHJ requirements govern field installation. Additional jurisdiction-specific requirements may also apply through local utility interconnection rules. Fig. 2 illustrates how these standards and requirements are applied within the U.S. framework.

For plug-in PV systems, this framework is less straightforward because the electrical source is connected through a cord-and-plug interface rather than through a conventional permanently wired DER interconnection. UL 3700, issued in December 2025 as an Outline of Investigation for Interactive Plug-In PV (PIPV) Equipment and Systems, represents an emerging product- and system-level pathway specifically addressing PIPV safety considerations. However, UL 3700 should not be interpreted as establishing a general statutory or utility interconnection exemption. Field installations remain subject to the applicable NEC, AHJ, and utility requirements.

3.1 IEEE 1547

IEEE 1547 series standards establish technical requirements for the interconnection and interoperability of DERs with electric power systems (EPS). IEEE 1547-2018 [14] is the base standard that provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general

requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. For inverter-based PV systems, IEEE 1547 requirements are important because they define the expected behavior of DERs during normal and abnormal grid conditions, including voltage and frequency response, cease-to-energize behavior, and unintentional islanding performance. Under IEEE 1547-2018, a DER participating in an unintentional island must detect the island, cease to energize the Area EPS, and trip within 2 s of island formation, subject to the standard's specified conditions and permitted exceptions [13]. These requirements are central to utility confidence that the DER will not continue energizing the grid during an outage. IEEE 1547.1-2020 [15] specifies the type, production, commissioning, and periodic tests and evaluations that shall be performed to confirm that the interconnection and interoperation functions of equipment and systems interconnecting DERs with the EPS conform to IEEE 1547.

For plug-in PV systems, IEEE 1547-2018 and IEEE 1547.1-2020 remain relevant because the inverter must still behave as a grid-interactive DER. However, these standards do not by themselves establish a permitting pathway for a cord-and-plug source connection. They do not resolve all questions concerning receptacle configuration, branch-circuit loading, connector touch safety, mobility, field installation, or AHJ acceptance. IEEE 1547 compliance should therefore be viewed as an important component of the technical interconnection requirements rather than as a complete authorization pathway for plug-in PV deployment.

3.2 UL 1741

UL 1741 [16] is the primary U.S. product safety and certification standard for inverters, converters, controllers, and interconnection system equipment used with DERs. It provides the product certification framework used to verify that inverter-based DER equipment satisfies electrical safety and interconnection performance requirements, including unintentional islanding protection, abnormal operating performance, and interoperability with the electric power system. UL 1741 applies to both stand-alone and interactive equipment and states that its requirements for interactive equipment are to be used in conjunction with IEEE 1547 and IEEE 1547.1.

For grid-interactive equipment, applicable UL 1741 testing verifies unintentional islanding protection in conjunction with IEEE 1547 and IEEE 1547.1. The usual IEEE 1547-2018 requirement is to detect an unintentional island, cease to energize the Area EPS, and trip within 2 s, subject to the conditions and permitted exceptions in the standard [14, 13]. This is not a requirement applicable to every UL 1741-certified product regardless of operating mode, because the standard also covers stand-alone equipment. It also does not establish touch safety at exposed connector contacts.

Supplement A (SA) introduced so-called "smart inverter" capabilities, including functions such as specified power factor, low/high voltage ride-through, low/high frequency ride-through, Volt/VAR mode, Volt/Watt mode, frequency/Watt mode, and ramp-rate control. Supplement B (SB), published with the 3rd edition, aligns advanced-function testing with IEEE 1547-2018 and IEEE 1547.1-2020 and adds interoperability and communications testing. SB includes conformance testing using protocols such as IEEE 2030.5,

SunSpec Modbus, or IEEE 1815 (DNP3), which support monitoring, communications, and control of inverter functions. As of the May 21, 2026 revision, UL 1741 also includes Supplement SC for AC bidirectional electric vehicle supply equipment (BEVSE) and interconnection systems equipment (ISE) used with EVs having SAE J3072-compliant bidirectional onboard inverters. In this architecture, the EV's onboard inverter performs the grid-interactive power conversion, while the SC-certified BEVSE/ISE provides an oversight and interconnection function. It communicates with the EV through SAE J3072, verifies that the vehicle is authorized and appropriately configured for the applicable grid requirements, and monitors or controls power export to prevent unauthorized or noncompliant grid interaction. Supplement SC therefore establishes a certification pathway for AC vehicle-to-grid (V2G) applications in which the inverter is located onboard the vehicle.

For MEGA®-type systems, UL 1741 certification of the inverter or interconnection equipment would provide an important foundation for utility and AHJ acceptance. However, UL 1741 certification alone does not address all plug-in deployment questions. In particular, it does not directly resolve whether a DER may backfeed through a cord-and-plug connection, whether a specific receptacle can be used as the connection interface, how branch-circuit loading should be evaluated, or how mobile deployment and relocation should be treated by AHJs.

3.3 UL 3700

UL 3700, *Outline of Investigation for Interactive Plug-In PV (PIPV) Equipment and Systems*, was first published as Issue No. 1 on December 11, 2025, followed by Issue No. 2 on October 1, 2026 [17, 18]. It provides a system-level evaluation framework for PIPV equipment and systems using an AC or DC interconnection cord and PIPV plug to connect to a permanently installed PIPV receptacle. Its scope includes movable equipment and complete PIPV equipment that can be interconnected to form a PIPV system. Sections 6.4.2 and 6.4.3 address 120 V single-phase and 120/240 V split-phase output configurations, respectively. Both remain subject to the outline's connector requirements, including the proprietary configuration specified in Section 6.4.1.3; the output voltage alone does not establish acceptance of a standard receptacle [18].

Issue No. 1 limited PV modules and PV DC circuits to a maximum open-circuit voltage of 64 Vdc at outline test conditions, corresponding to 80 Vdc after applying a 1.25 cold-temperature correction factor. Issue No. 2 increases these limits to 480 Vdc and 600 Vdc, respectively. This expansion is accompanied by additional protection requirements. In particular, Sections 6.10.4 and 6.10.5 address construction and barriers for higher voltage DC circuits, including enclosure of DC wiring to prevent user access.

Issue No. 2 excludes roof-mounted PV, building-integrated PV, and PV equipment or systems permanently electrically connected to premises wiring or the point of service. Section 1.9 requires components of the connected electric power system circuit, including connectors, receptacles, circuit-interrupting devices, and overcurrent protective devices, to be listed and identified for bidirectional current flow and installed in accordance with applicable NFPA 70, National Electrical Code, requirements. These provisions distinguish

the detachable PIPV equipment connection from the permanently installed receptacle and associated premises wiring.

UL 3700 supplements other product requirements. Section 6.5.2.1 requires grid interactive inverters to comply with UL 1741 requirements for interactive equipment and its references, including Supplement SB. The outline also addresses accessible live parts, connector configuration, branch-circuit overload, bidirectional GFCI protection, power control functions, mounting, labeling, and installation instructions.

Two additional provisions are particularly relevant to MEGA-type configurations. Section 6.12.1, retained in both issues, limits a battery pack consisting of a battery and integral battery management system to a capacity no greater than 1 kWh and requires compliance with UL 1973. GismoPower reports optional 16 or 32 kWh storage configurations, making the battery-pack architecture and this scope limit a specific applicability issue rather than a hypothetical concern [11]. The pack limit applies to covered PIPV equipment regardless of AC connection voltage. Total system energy and individual pack capacity must be distinguished. UL 9540 is relevant to evaluating the complete energy storage system, together with applicable battery and inverter requirements; it does not automatically remove UL 3700's pack limit or establish acceptance of the combined mobile appliance [19]. In Issue No. 2, Section 6.6.1 prohibits EV chargers from exporting to the EPS and expressly prohibits UL 9741 EV chargers or EV power export equipment from exporting to premises wiring within the covered PIPV system. It permits specified vehicle power export for stand-alone convenience-receptacle operation isolated from premises wiring. A Level 2 charger operating only as a load to charge a vehicle is distinct from vehicle-to-premises export; Section 6.6.1 permits charging equipment subject to its applicable product requirements.

Accordingly, the applicability of UL 3700 to MEGA should be assessed against the complete configuration, including PV voltage, DC access protection, inverter functionality, connection arrangement, battery pack configuration, EV charging or power export functions, and operating modes. Neither the expanded DC voltage range nor a particular AC connection voltage establishes a complete certification pathway for every configuration. Applicable product evaluation, installation, and utility interconnection requirements remain relevant.

3.4 UL 3141

UL 3141 [20], *Outline of Investigation for Power Control Systems (PCS)*, addresses power control systems that control one or more sources, loads, or combinations of sources and loads. UL 3141 includes evaluation of control functions intended to mitigate overload conditions, including busbar, feeder-conductor, branch-conductor, and single-source overload.

UL 3141 may therefore be relevant to PIPV configurations in which coordinated monitoring and control are used to prevent conductors or electrical equipment from exceeding their ratings. For example, a PCS may provide export limiting, branch-conductor overload control, or both, depending on its evaluated functions. Power export limiting at the PCC does not by itself provide premises-conductor overload protection [21].

H.R. 10851 uses the term PCS in its device definitions but does not specify in those provisions the required sensing boundary, response time, failure behavior, or particular UL 3141 control function [8]. Consequently, a statutory PCS condition should not be assumed to demonstrate either non-export performance or branch-conductor overload protection without a defined and evaluated function.

However, UL 3141 should not be treated as a general exemption from interconnection or installation requirements. A PCS does not by itself resolve touch safety, connector compatibility, GFCI protection, grounding and bonding, labeling, or utility interconnection requirements. For MEGA, PCS functionality should therefore be considered one element of a broader system-safety and interconnection strategy.

3.5 UL 943

UL 943 [22], *Ground-Fault Circuit-Interrupters*, specifies requirements for Class A GFCI intended to provide personnel protection on applicable grounded AC circuits. The standard addresses the functional performance, construction, and marking of GFCI devices. Class A GFCIs are commonly used where protection against electric-shock hazards is required under the applicable electrical code.

UL 943 is particularly relevant to PIPV systems because a PIPV system can introduce bidirectional power flow into a premises circuit. A GFCI used on such a circuit must be evaluated for the intended current flow configuration; conventional GFCI protection should not automatically be assumed to be suitable for a source that can backfeed the circuit. For PIPV applications, UL 3700 therefore specifies requirements for bidirectional Class A GFCI protection where applicable, including requirements for the circuit and PIPV equipment.

3.6 NEC

NFPA 70, the National Electrical Code (NEC), is the principal model electrical installation code used by AHJs in the United States. The applicable edition and locally adopted amendments determine the enforceable requirements in a particular jurisdiction. The NEC is important for PIPV because product listing alone does not establish that a particular field installation complies with the adopted electrical code.

Several NEC articles may be relevant to PIPV systems, including Article 690 for PV systems, Article 705 for interconnected electric power production sources, Article 210 for branch circuits, Article 240 for overcurrent protection, Article 625 for EV charging and power export, Article 706 for energy storage where applicable, and other provisions addressing grounding and bonding, GFCI protection, disconnecting means, wiring methods, and equipment installation.

For conventional PV systems, the electrical source is typically connected to premises wiring through a permanently installed wiring method and dedicated interconnection equipment. A PIPV system introduces a different installation architecture because the source can be connected to premises wiring through a cord-and-plug interface. This configuration raises additional questions regarding the suitability of the receptacle and

plug, bidirectional current flow, branch-circuit loading, protection of conductors and equipment, disconnecting means, and protection against user access to energized conductors. The existing NEC framework was not developed specifically around the complete set of characteristics associated with mobile PIPV systems, particularly a user-accessible cord-and-plug connection combined with several kilowatts of generation.

Article 625 illustrates why charging and generation must be distinguished. NEC 2023 Section 625.44(A)(3) permits specified cord-and-plug connections for portable EVSE, including specified 125/250 V receptacles rated up to 60 A. This is a receptacle rating, not an unconditional allowance for 60 A continuous charging. Applicable load sizing, protection, and listing requirements still apply. Section 625.48 addresses equipment intended for power export, including listing and marking requirements. Permission for a charging connection does not independently establish acceptance of a PV source or every bidirectional configuration [23].

Earlier DOE-supported work also examined code compliance and standardized interconnection interfaces as part of a coordinated installation process [5]. The Fraunhofer project used a purpose-designed solar connector and premises-side receptacle with integrated overcurrent protection and electronic approval procedures; it should not be treated as evidence of acceptance of an ordinary NEMA-connected mobile appliance. Such research provides useful context but does not replace the locally adopted NEC or current product evaluation requirements.

3.7 Summary of Related Standards

The standards and codes summarized in Table 2 address different aspects of MEGA® deployment. IEEE 1547 establishes the technical requirements for DER interconnection and interoperability, while IEEE 1547.1 defines corresponding conformance tests. UL 1741 provides product-level requirements for applicable inverter, converter, controller, and interconnection equipment. UL 3700 addresses additional system-level considerations specific to interactive PIPV equipment and systems, while UL 3141 may provide a pathway for power control functions such as export limitation and overload mitigation. The NEC and applicable state, local, and utility requirements govern the field installation and authorization of the system. Therefore, successful deployment of a MEGA®-type system requires a coordinated compliance approach rather than reliance on a single standard or certification.

Table 2: Summary of Technical Standards and Requirements Relevant to MEGA®-Type Systems

Standard / Code	Primary role	Key requirements or functions	Relevance to MEGA®
IEEE 1547-2018	DER interconnection and interoperability	Establishes technical requirements for interconnection and interoperability between DERs and electric power systems, including normal and abnormal operating performance, power quality, islanding, voltage/frequency response, and interoperability.	Provides the principal technical framework for evaluating MEGA® as a grid-interactive DER. It addresses DER behavior at the EPS interface but does not by itself establish a permitting pathway for a mobile cord-and-plug installation.
IEEE 1547.1-2020	DER conformance testing	Defines type, production, commissioning, periodic tests, and evaluations used to verify that DER equipment and systems conform to IEEE 1547 interconnection and interoperability requirements.	Provides the testing framework for demonstrating applicable IEEE 1547 functions of the inverter and interconnection system. It does not replace NEC installation requirements or utility interconnection procedures.
UL 1741	Product safety and certification for DER power-conversion and interconnection equipment	Covers inverters, converters, controllers, and interconnection system equipment used with DERs. Applicable requirements address product safety and grid-interactive functions. The May 21, 2026 revision added Supplement SC for AC bidirectional EV supply equipment/interconnection systems equipment used with EVs having SAE J3072 bidirectional onboard inverters.	Provides an important product-certification basis for MEGA®'s inverter and applicable interconnection equipment. Certification of individual components does not, by itself, resolve all system-level cord-and-plug, installation, or AHJ issues.

Table 2: Summary of Technical Standards and Requirements Relevant to MEGA®-Type Systems, continued

Standard / Code	Primary role	Key requirements or functions	Relevance to MEGA®
UL 3700	PIPV system-level safety evaluation	Provides an emerging evaluation framework specifically for interactive plug-in PV equipment and systems using a PIPV plug and permanently installed PIPV receptacle. The current outline addresses movable PIPV equipment and includes requirements related to accessible energized parts, bidirectional current flow, installation, and system-level safety.	Potentially provides a more direct pathway for PIPV-type equipment than relying only on conventional inverter certification. Its scope limitations must be checked carefully against MEGA®'s electrical architecture, including PV voltage and access protection, connector configuration, battery-pack capacity, and operating modes.
UL 3141	Power Control Systems (PCS)	Addresses power control systems used to control electrical power flows and support functions such as overload mitigation and power import/export control.	May be relevant when MEGA® uses active power control to limit export or manage branch-circuit loading. PCS certification does not eliminate other product, installation, or interconnection requirements.
UL 943	Ground-Fault Circuit-Interrupters (GFCIs)	Provides requirements for GFCI devices intended to protect against electric-shock hazards. For PIPV applications, the suitability of GFCI equipment for bidirectional current flow is an important consideration.	Relevant where GFCI protection is required by the installation. The PIPV system and circuit must use GFCI equipment appropriate for the intended bidirectional operating conditions where required by the applicable product evaluation and installation requirements.

Table 2: Summary of Technical Standards and Requirements Relevant to MEGA®-Type Systems, continued

Standard / Code	Primary role	Key requirements or functions	Relevance to MEGA®
NEC (NFPA 70)	Field installation and electrical safety code	Provides installation requirements for wiring, branch circuits, overcurrent protection, grounding and bonding, GFCI protection, disconnecting means, PV systems, interconnected power sources, and other electrical equipment. The enforceable requirements depend on the NEC edition adopted by the applicable jurisdiction and any local amendments.	Determines whether a specific MEGA® installation is acceptable to the AHJ. Product certification does not substitute for NEC-compliant field installation. The cord-and-plug architecture may require AHJ interpretation of applicable provisions.

4.0 Technical, Regulatory, and Procedural Barriers

Although plug-in PV has significant potential to expand access to distributed solar generation, deployment in the United States presents several technical, regulatory, and procedural challenges. Three safety concerns that have received particular attention in PIPV discussions are touch safety, branch-circuit overload or “breaker masking,” and bidirectional GFCI protection.

Regulatory power thresholds define eligibility for particular administrative treatment; they do not independently establish safety. Evaluation must also address accessible voltage and energy, de-energization time, current relative to conductor and device ratings, and applicable fault conditions. Power rating remains relevant to loading, but cannot substitute for assessment of the complete circuit and protection configuration.

4.1 Touch Safety

Touch safety concerns electric shock from accessible plug contacts or other conductors during and after connector separation. A conventional attachment plug normally supplies power to a load. Using it as the output interface of a power-producing device introduces the possibility that its contacts remain energized after disconnection. Depending on the connector configuration, plug blades may also be accessible during insertion or removal.

For grid-interactive equipment, UL 1741 provides a framework for evaluating applicable interconnection functions in conjunction with IEEE 1547 and IEEE 1547.1. The usual IEEE 1547-2018 unintentional-islanding response is 2 s, subject to specified conditions and permitted exceptions. This grid-interconnection requirement does not, by itself, demonstrate touch safety at accessible plug contacts. UL’s PIPV safety white paper identifies the need for protection beyond utility-interactive performance alone [24, 13].

UL 3700 addresses accessible live parts through connector construction and, where permitted, User Accessible Inverter Output Protection (UAIOP). Annex A requires UAIOP to de-energize and isolate accessible PIPV output circuits, reducing voltage below 15 Vac or 30 Vdc in less than 0.5 s after the AC connection is unmated. When combined with the specified PIPV overvoltage and undervoltage protection, the response time must not exceed 160 ms. UAIOP must also address single-point failures in hardware and software/firmware through the functional-safety requirements referenced in UL 1741, Section 97 [18].

These touch-safety provisions do not independently establish acceptance of a conventional NEMA connector. UL 3700 Issue No. 2, Section 6.4.1.3, separately requires proprietary connector configurations that cannot mate with specified commonly available connectors, including NEMA configurations. The exceptions in Sections 6.4.2.2 and 6.4.3.2 permit accessible terminals when unmated if Annex A is satisfied; they do not expressly waive the configuration requirement. Section 6.4.1.7 additionally requires latching or locking connectors and either the UL 6703 current-interruption sequence or the specified tool-operated, marked alternative with UL 1682 abnormal-overload testing [18].

GismoPower proposes a performance-based approach in which rapid de-energization

of accessible output contacts would provide touch protection for a conventional NEMA connection on a dedicated 240 V circuit. This is a proposal for evaluation, rather than a demonstrated compliance finding or an accepted alternative under UL 3700 Issue No. 2. Evaluation would need to establish triggering conditions, accessible voltage and energy, response time, isolation, and performance under applicable single-fault conditions. Testing should address connector separation explicitly and verify that the protection remains effective without improperly interfering with required grid ride-through behavior.

A standard-connector pathway would require applicable standards clarification or revision, or another accepted evaluation pathway. Functional touch protection and connector configuration can address different hazards; the effectiveness of an alternative arrangement needs to be assessed against the complete set of applicable safety objectives.

The standard 120 V outlet connection described in H.R. 10851 [8] differs from the proprietary connector arrangement specified in UL 3700 Issue No. 2. However, the bill identifies certification organizations rather than mandating certification specifically to UL 3700. This is an issue requiring alignment of proposed policy, applicable product evaluation, and installation requirements.

4.2 Breaker Masking and Branch Circuit Overload

Breaker masking occurs when a plug-in PV source supplies current to loads on a branch circuit in a way that reduces the current seen by the upstream circuit breaker, while portions of the branch circuit may still carry current above their intended ampacity. This creates a potential conductor overheating and fire-risk concern if PIPV is connected to ordinary branch circuits without additional safeguards. UL's PIPV safety white paper [24] emphasizes that PIPV requires special attention to overcurrent protection because NEC Articles 210 and 240 are based on the conventional assumption of a single source supplying power from the panelboard to loads. A PIPV source backfeeding a receptacle introduces an additional source of current that may not be protected by the upstream branch-circuit overcurrent protective device. The combined utility and PIPV current can overload conductors or connected equipment, creating electric-shock and fire risks. UL notes that this risk increases with larger PIPV sources or multiple PIPV units on the same circuit, especially where standard NEMA 5-15 plugs are used by consumers without electrical training.

For a correctly configured dedicated branch circuit with no separately connected loads, the shared-circuit masking mechanism described above is avoided. This does not remove the need to verify circuit ratings, appliance protection, panelboard loading, and suitability of the receiving connection. The distinction depends on circuit topology rather than voltage alone.

UL 3700 identifies several mitigation strategies. Their applicability depends on the circuit topology and evaluated configuration; they are not interchangeable safeguards. The first is a *dedicated circuit with a unique plug-in PV receptacle*. In this configuration, the PIPV system is installed only on a dedicated branch circuit so that no other loads share the circuit. The PIPV source backfeeds only through that dedicated circuit to a properly rated overcurrent protective device at the panel. A uniquely configured plug-and-receptacle interface, incompatible with standard NEMA receptacles, prevents the

user from relocating the PIPV unit to an unprotected circuit.

The second mitigation is a *unique PIPV receptacle with integral overcurrent protection*. Where a branch circuit includes multiple receptacles, the first receptacle can be replaced with a uniquely configured PIPV receptacle that incorporates overcurrent protection. This approach helps ensure that downstream conductors and connected loads remain protected from combined current supplied by both the utility and the PIPV source.

The third mitigation is a *unique PIPV receptacle with oversized conductors*. In this approach, the circuit is evaluated or modified so that the conductors and connected equipment are rated for the sum of the branch-circuit overcurrent protection and the PIPV source contribution. UL 3700 reflects this concept by requiring instructions that, for oversized-conductor installations, the sum of the branch-circuit overcurrent protective device rating plus 125% of the PIPV source output current must not exceed the rating of the branch-circuit conductors and equipment.

The fourth mitigation is use of a *power control system with a unique plug-in PV receptacle*. A PCS evaluated under UL 3141 can monitor and regulate current and/or power from multiple sources to help keep controlled conductors within safe operating limits. UL 3700 specifically requires PIPV systems using PCS functionality to comply with UL 3141 branch-conductor-overload protection requirements for dedicated and non-dedicated circuits. To preserve the integrity of this safety strategy, the PIPV system should connect only through a uniquely configured receptacle associated with PCS-protected circuitry, preventing users from plugging the device into receptacles that lack PCS protection.

4.3 Bidirectional GFCI Protection

Ground fault circuit interrupters (GFCIs) are life safety devices designed to reduce the risk of electric shock by disconnecting a circuit when a ground fault is detected. The NEC requires GFCI protection in many locations where water or user accessibility increases shock risk, including outdoor areas, garages, kitchens, bathrooms, and other wet or damp locations. These are also common locations where plug-in PV systems may be installed or connected, making GFCI compatibility an important permitting and safety issue [24].

A central challenge for PIPV is that the system intentionally backfeeds power into a premises circuit. Conventional GFCI breakers and receptacles are generally marked and evaluated for current flow from the line side to the load side, not for bidirectional current flow. Research published in 2025 [6] identified the lack of officially rated bidirectional GFCIs and the historical lack of an official UL test procedure for such devices as a significant barrier to code compliance and safe deployment of plug-in DERs.

UL's 2025 PIPV safety white paper discussed updates to UL 943 needed to support bidirectional power flow. For a proposed deployment, the relevant question is whether the specified devices are properly evaluated and certified bidirectional GFCI devices with appropriate markings for bidirectional use [24]. The same white paper also highlights that a conventional circuit-breaker-type GFCI may interrupt only the ungrounded conductor while leaving the grounded conductor connected through the panelboard neutral-ground bond, which may not fully interrupt a PV inverter ground-fault current path under some PIPV conditions [24].

UL 3700 directly addresses this issue by requiring both the PIPV equipment and the branch circuit to which it is connected to be protected by bidirectional Class A GFCI protection complying with UL 943. Where the PIPV supply connection cable includes a neutral/grounded conductor, the bidirectional Class A GFCI must also interrupt the neutral/grounded conductor. For PIPV intended for dedicated circuits, UL 3700 requires either integral Class A GFCI protection or installation instructions specifying upstream bidirectional Class A GFCI circuit breakers that comply with these requirements. For PIPV intended for non-dedicated circuits, UL 3700 requires integral Class A GFCI protection. Instructions must identify evaluated protective devices and their conditions of use; a generic substitution should not be assumed acceptable. Additional protection requirements apply to specified stand-alone or isolated-output configurations [18].

4.4 NEC and AHJ Interpretation

The NEC provides requirements relevant to PV systems, interconnected power sources, branch circuits, overcurrent protection, GFCI protection, wiring methods, grounding and bonding, and disconnecting means. However, a consistently recognized installation pathway for medium-power mobile PIPV equipment using a cord-and-plug connection has not been established across jurisdictions.

As a result, AHJs may need to determine how existing requirements apply to the specific equipment, connection method, and installation. The uncertainty is particularly important for systems such as MEGA because the system combines several functions that are typically evaluated separately: PV generation, grid interconnection, EV charging, mobility, and a cord-and-plug source connection.

The resulting permitting process may therefore depend on the product listing, installation instructions, adopted NEC edition, local amendments, utility requirements, and AHJ interpretation. A product-level certification should reduce uncertainty, but it does not eliminate the need for field-installation and interconnection approval.

Proposed NEC amendments illustrate ongoing work on this gap. As of the October 29, 2026 review cutoff, NFPA's proposed TIA Log No. 1951 identifies a PIPV definition and a proposed Article 705 Part IV covering cord-and-plug power production sources, with a public-comment closing date of November 20, 2026 [25]. Publication for comment does not establish approval, adoption, or an authorized installation pathway. Final provisions and their local applicability would need to be confirmed before use.

Recent Nevada proceedings illustrate the need to coordinate local permitting and utility interconnection requirements. In its October 16, 2026 order in Docket 26-09004, the Public Utilities Commission of Nevada declined to initiate rulemaking on the proposed regulation and directed an investigation into plug-in PV interconnection, including classification, certification, and the treatment of local permitting or inspection exemptions [26]. The resulting investigation was assigned Docket 26-10020 [27]. The order did not establish product acceptance or an interconnection exemption.

County correspondence provides a related example of distinct review responsibilities. A September 2026 Clark County Building Official determination identified a building-permit and inspection exemption for the specified portable, unanchored configuration

while requiring an electrical permit for the dedicated outlet. A subsequent notice continued to apply land-use setback requirements to the installation [28, 29]. These records illustrate that acceptance under one review process does not independently establish acceptance under all applicable requirements.

4.5 Connection and Commissioning of Relocatable Equipment

This paper considers appliances with onboard power conversion and, where included, EV charging and power-control functions connected through a premises circuit and receptacle. The applicable evaluation and installation requirements depend on the complete equipment configuration, connection method, and operating mode. Certification of an onboard inverter provides evidence of its evaluated interconnection functions, but does not independently establish acceptance of the complete mobile appliance or its connection to a particular premises circuit. Conversely, mobility alone does not establish that a separate stationary supervisory device is required. Applicable interconnection functions and settings should be verified at the reference point specified by the relevant requirements [14, 15].

Connection provisions should also be interpreted within their scope. UL 9741 describes several premises-connected EV power export configurations using permanent-connection language; these provisions should not be generalized into a prohibition on all cord-connected DERs [30]. UL 3700 Issue No. 2 separately restricts vehicle-to-premises export within its covered PIPV configurations. This restriction should be distinguished from Level 2 EV charging operating as a load [18].

Relocation procedures should distinguish physical repositioning within unchanged approved deployment conditions from a change in connection point, service address, or utility territory. A proposed streamlined process could combine equipment and address registration with verification of the receiving circuit, applicable settings, and operating authorization. The extent of any additional commissioning or review should reflect the changes introduced and the applicable manufacturer, AHJ, and utility requirements. These functions should be assessed without presuming a particular onboard or premises-side control architecture.

4.6 Existing Distribution-Impact Evidence and Remaining Questions

The 2023 NC State/FREEDM study examined household and aggregated net-load profiles, PV generation, EV charging, and selected transformer-loading scenarios [12]. Its results indicate that coordinating charging with solar production can increase local solar use and reduce export in the modeled scenarios. They also illustrate that benefits depend on charging schedules, demand, and equipment loading; coordinated charging does not demonstrate zero export under every condition.

A subsequent SLAC study evaluated MEGA deployment in a modeled distribution network using Arras Energy, based on GridLAB-D, with one-minute simulations spanning a full year [31]. The study examined residential and workplace charging scenarios

and presented results for 200 and 2,000 MEGA units. For the modeled conditions, the authors reported no significant adverse effects on distribution assets or voltage, with voltages at the 198 secondary connection nodes remaining within the reported $\pm 5\%$ band. These findings supplement the NC State/FREEDM analysis by providing network-level simulation evidence.

Their applicability remains conditional on the modeled equipment, network, generation, and charging assumptions; they do not establish universal hosting capacity, protection coordination, or suitability for every deployment. Further work should examine aggregate export, voltage and loading under different secondary-network conditions, and any relevant protection interactions.

4.7 Gap Analysis and Potential Gap Closure Measures

Table 3 summarizes the principal gaps and potential closure measures. The proposed measures are research and policy options; they should not be interpreted as findings that a notification-only pathway is currently authorized or technically justified in every jurisdiction.

Table 3: Gap Analysis for MEGA®-Type Systems

Gap	Current condition	Significance for MEGA®	Potential gap-closure measure
Product classification	Stakeholders classified MEGA® as either a DER or a case-by-case product.	Classification affects which code articles, product standards, permit forms, and interconnection rules apply.	Develop a functional definition based on mobility, maximum AC output, voltage, current, circuit type, export mode, and EV charging functionality.
Certification pathway	Stakeholders requested certification but did not identify a single consistent system-level pathway.	Subsystem certification may not establish acceptance of the complete mobile PIPV/EV charging configuration.	Prepare a certification matrix mapping IEEE 1547/UL 1741, UL 3700, UL 3141, UL 943, and any applicable EVSE requirements to specific system functions.
NEC installation pathway	No universally adopted PIPV-specific installation pathway resolves all medium-power configurations.	Product evaluation alone does not establish code acceptance.	Clarify adopted-code application and monitor proposed PIPV amendments, including TIA Log No. 1951; proposals are not approved requirements [25].

Table 3: Gap Analysis for MEGA®-Type Systems, continued

Gap	Current condition	Significance for MEGA®	Potential gap-closure measure
Connection method and evaluation pathway	Some product pathways use permanent-connection language; IEEE 1547 applicability and installed-system conformity are separate questions.	A listed onboard inverter does not settle the complete appliance connection pathway.	Clarify cord-connected configurations through standards processes and evaluation with the laboratory, AHJ, and utility; do not infer a stationary-device mandate solely from mobility.
Touch safety and connector configuration	Anti-islanding alone does not establish touch safety. UL 3700 separately specifies proprietary connectors.	UAIOP does not waive connector requirements for a NEMA-connected appliance.	Evaluate standard-connector options for defined circuits using verified UAIOP, together with misconnection prevention, circuit protection, and connector performance. Identify necessary standards revisions or another accepted evaluation pathway.
Branch-circuit overload	Backfeed can mask current seen by the upstream breaker.	Larger power levels increase the consequences of incorrect circuit assumptions.	Select a topology-specific, evaluated overload strategy: a dedicated circuit, coordinated integral protection, appropriately rated conductors and devices, or applicable UL 3141 branch-conductor-overload control.
Bidirectional GFCI	Conventional GFCI protection may not be evaluated for reverse power flow.	MEGA® may be used outdoors, where GFCI protection is commonly required.	Require evaluated bidirectional Class A GFCI protection and verify neutral interruption where applicable. UL has identified the need for evaluated and certified bidirectional GFCI devices on PIPV circuits.

Table 3: Gap Analysis for MEGA®-Type Systems, continued

Gap	Current condition	Significance for MEGA®	Potential gap-closure measure
Export control	Utility treatment of non-export, limited-export, and inadvertent export varies.	Utilities may require full review even when the system is intended to avoid export.	Define operating mode, measurement boundary, response time, commissioning test, and response to sensing, communications, and control power loss. UL 3141 tests PCS functions under rapid source/load changes and loss-of-control conditions.
Distribution system impact	The NC State/FREEDM and SLAC studies provide operational and network-simulation evidence for selected PV/EV scenarios [12, 31].	Operational benefits do not establish hosting capacity or protection compatibility for every secondary network.	Extend those analyses across representative secondary circuits, feeders, export modes, storage configurations, and protection arrangements.
Mobility, relocation, and commissioning	Repositioning at an approved connection differs from changing receptacles, service addresses, or utilities.	An unchanged electrical configuration need not trigger the same process as a new deployment.	Develop a proportionate relocation process combining serial-number and address registration, updates when the connection point or service address changes, and verification of circuit suitability, applicable settings, and any required commissioning or authorization. Registration can support utility planning but does not independently establish installation or interconnection acceptance.
Battery configuration	UL 3700 limits individual battery packs with integral BMS to 1 kWh; the manufacturer reports 16/32 kWh storage options.	Pack architecture and complete-system evaluation require explicit assessment.	Assess UL 1973 and UL 9540 applicability and installation requirements. UL 9540 does not independently waive UL 3700 limits or approve the mobile assembly.

Table 3: Gap Analysis for MEGA®-Type Systems, continued

Gap	Current condition	Significance for MEGA®	Potential gap-closure measure
EV power export and stand-alone operation	UL 3700 Issue No. 2 restricts EVPE export to premises wiring and limits stand-alone inverter output to specified isolated convenience-receptacle operation.	Charging-only Level 2 EVSE is a load. Vehicle export or premises backup may require a different evaluation pathway.	Distinguish PV export, EV charging, EV power export, and premises-backup modes; identify the applicable standards and protection requirements for each.
AHJ/utility coordination	Product, installation, and interconnection reviews are handled by different entities.	Conflicting or duplicative requirements can delay approval.	Use a responsibility matrix, standardized data package, and defined escalation process between notification, expedited review, and full review.

5.0 Proposed Permitting Framework

According to a 2026 analysis by the Southern Alliance for Clean Energy [32], in many utility territories in the United States, connecting a plug-in PV unit to a residential outlet or household circuit may require a formal interconnection application to the serving utility, utility technical review that can take weeks to months, a signed interconnection agreement, and, in some cases, an electrical permit, inspection, or external disconnect switch. Utility approval may also be delayed, conditioned, or denied where existing interconnection rules do not clearly recognize appliance-class or plug-in DER configurations. These procedures were generally developed for conventional, permanently installed DERs and may be difficult to apply efficiently to mobile or appliance-class PV products.

To address these challenges, this paper proposes a layered, risk-informed permitting framework for MEGA®-type systems. The purpose of the framework is not to eliminate safety, installation, or interconnection review. Rather, it is to scale the level of review to the risk presented by the equipment, installation, operating mode, and deployment site. The proposed framework distinguishes among: (1) prequalified notification-only deployments, (2) standardized installations requiring expedited AHJ or utility review, and (3) nonstandard installations requiring full permit and utility interconnection review.

5.1 Permitting Principles

A layered permitting framework for MEGA®-type plug-in PV appliances should recognize that product safety certification, NEC-compliant field installation, and utility interconnection review are related but distinct functions. The following principles should guide the review process:

- **Separate product safety from site installation.** Product certification or evaluation, such as UL 1741 inverter certification, IEEE 1547 conformance, UL 3700 PIPV evaluation where applicable, or other relevant NRTL evaluation, provides an important safety basis. However, product certification does not by itself verify the suitability of a particular field installation. AHJs may still need to evaluate the receptacle or connection point, branch circuit, grounding and bonding, overcurrent protection, GFCI protection, disconnecting means, labeling, and compliance with manufacturer installation instructions.

- **Clarify jurisdictional roles.** AHJs should review field installation and NEC compliance. Utilities should address interconnection, export behavior, metering, and distribution-system visibility. NRTLs should evaluate product safety and certification. For mobile or appliance-class DERs, the permitting framework should clarify how these roles apply when the product is not a conventional permanently installed PV system.

- **Use dedicated or otherwise protected circuits for medium-size systems.** MEGA®-type systems are materially different from small 120 V plug-in PV devices because of their higher power level, 240 V connection, and potential use with

dedicated branch circuits. Streamlined review should therefore prioritize dedicated 240 V circuits, dedicated PIPV receptacles, or other engineered circuit protection approaches. Dedicated or otherwise protected circuits reduce uncertainty regarding branch circuit topology and help mitigate concerns related to breaker masking, conductor overload, and unintended interaction with other loads.

- **Require documented suitability for bidirectional power flow.** The PIPV equipment, receptacle, branch-circuit components, overcurrent protection, disconnecting means, and GFCI protection should be documented as suitable for the intended current direction and operating mode. Where GFCI protection is required, the documentation should identify whether the device or protection scheme is suitable for bidirectional current flow. This is important because conventional branch circuit devices may not have been evaluated for operation with a plug-in source that can backfeed the circuit.

- **Distinguish export control from premises-wiring protection.** Non-export or limited-export operation can reduce utility-facing distribution impacts and may support a streamlined utility review pathway. However, export control should not be treated as a substitute for NEC-compliant branch circuit and premises-wiring protection. If a power control system or export control function is used, the applicant should document the controlled electrical boundary, export limit, failure response, commissioning procedure, and applicable product evaluation.

- **Require standardized documentation.** Streamlined permitting should depend on a complete and standardized documentation package. This package should include equipment specifications, listing or certification evidence, a simplified one-line diagram, circuit and receptacle information, protection device documentation, export control settings if applicable, labels, owner instructions, and utility notification or registration information.

- **Account for mobility and relocation.** Because MEGA® is intended to function as a mobile appliance-class DER, the permitting framework should include a registration or update process when the unit is relocated. Address-based registration can help utilities and AHJs maintain visibility into where generation assets are operating without requiring a full interconnection study for every standardized deployment.

- **Scale review effort to deployment risk.** Standardized, prequalified deployments should be eligible for administrative notification or expedited review. Nonstandard configurations, export capable systems without approved controls, installations on non-dedicated circuits without evaluated overload mitigation, systems lacking adequate protection documentation, or sites with unusual electrical or distribution-system conditions should undergo full AHJ and utility review.

5.2 International Reference: German Balcony PV Compliance Checklist

Germany's simplified balcony PV pathway provides a useful example of how a jurisdiction can translate technical requirements into a consumer-facing compliance checklist. Although German requirements are not directly transferable to the United States, the German model illustrates how small plug-in PV systems can be managed through standardized product requirements, registration, metering rules, and installation guidance.

A typical German balcony PV compliance checklist may include elements such as:

- inverter output limited to the applicable national threshold, commonly 800 VA for simplified balcony PV deployment;
- inverter compliance with applicable grid connection requirements, such as VDE-AR-N 4105 [33];
- limits on connected PV module capacity, which may vary depending on the product category, connector configuration, and applicable national rules;
- integrated grid protection in certified inverters;
- registration in the Marktstammdatenregister (MaStR) within the required registration period;
- metering compatibility or meter replacement where required;
- suitable mounting, fastening, and periodic inspection practices; and
- landlord, condominium, or building owner coordination where required.

This checklist is not directly transferable to U.S. deployments at either 120 or 240 V because product requirements, circuit configurations, registration, metering, and approval procedures differ among jurisdictions. The medium-size 240 V appliances considered here also differ in rating and architecture from the 800 VA balcony PV devices addressed by the checklist. The German experience nevertheless illustrates the value of standardized compliance documentation and clearly defined eligibility conditions. A U.S. MEGA® checklist should similarly identify the preconditions for expedited review, including product listing or evaluation, a dedicated 240 V circuit or other approved protected connection point, documented protection, touch-safety measures, utility notification or registration, labeling, and site documentation.

5.3 Three-Tier Approval Framework

The proposed framework establishes three approval pathways. The appropriate pathway would be determined by the characteristics of the equipment, installation, operating mode, and deployment site. The pathways are intended to provide a progression from highly

standardized, lower-risk deployments toward conventional project specific review where needed.

5.3.1 Pathway 1: Notification-Only Deployment

The notification-only pathway is a potential future administrative process for deployments that satisfy predefined product, installation, and operating criteria. It would be available only where authorized by the applicable governing authorities, with utility and AHJ requirements addressed within their respective jurisdictions. Notification-only treatment would streamline project-specific review while retaining applicable safety, installation, and interconnection requirements.

A MEGA®-type deployment may be eligible for notification-only treatment if all of the following conditions are satisfied:

- the complete system configuration has been listed, certified, or otherwise evaluated through a process accepted by the applicable authorities;
- the inverter and interconnection equipment satisfy applicable IEEE 1547 and UL 1741 requirements;
- the system includes documented touch-safety protection for user-accessible output conductors or plug contacts;
- the connection point is a prequalified dedicated circuit, dedicated PIPV receptacle, or other protected connection point accepted under the pathway;
- the receptacle, conductors, overcurrent protection, GFCI protection, and other relevant circuit components are documented as suitable for the intended current direction, electrical ratings, and operating mode;
- panelboard busbar loading, accounting for all power sources at the service, satisfies applicable limits;
- the metering configuration is compatible with the accepted operating mode;
- applicable capacity or export limits for the service and any secondary-network or transformer screening criteria specified by the adopted pathway are satisfied;
- required disconnecting means, labeling, owner instructions, and emergency-response information are provided;
- the operating mode, including any non-export or limited-export settings, is accepted under the serving utility's notification-only pathway or has otherwise received the required prior approval;

- any export control or power control function relied upon for eligibility has been evaluated, configured, verified through applicable commissioning procedures, and documented;
- the proposed PV, storage, EV charging, and any power export or backup functions are within the scope and conditions of the accepted system evaluation; where included, storage classification and applicable installation conditions are accepted under the pathway;
- no new field wiring, circuit modification, or project-specific engineering is required, although routine site verification and commissioning may be necessary; and
- changes to the connection point, service address, operating mode, or other material conditions trigger applicable notification, eligibility verification, and any required commissioning or approval; physical repositioning within unchanged approved deployment conditions does not by itself constitute a new interconnection.

Under this pathway, the customer or qualified installer would submit a standardized notification containing the equipment identification, serial number, installation address, maximum AC output, connection configuration, operating mode, export control information where applicable, and supporting compliance documentation. Eligibility would be checked against predefined criteria. Project-specific engineering review would generally not be required for qualifying deployments, but additional review could be requested where the submitted information or site conditions indicate that those criteria are not satisfied. The adopted pathway would specify notification timing and any acknowledgment required before operation. Verified non-export operation may support reduced review, but does not independently remove applicable installation, protection, metering, or utility screening requirements.

A deployment should be referred to Pathway 2 or Pathway 3, as appropriate, if it requires new electrical work, uses a connection configuration outside the prequalified criteria, lacks an accepted operating mode, has unverified protection or control settings, or presents site conditions requiring additional evaluation. Missing information could first be resolved through the notification process where permitted by the adopted procedure.

5.3.2 Pathway 2: Expedited Interconnection and Permitting Review

The expedited pathway is intended for standardized systems that satisfy predefined technical and safety criteria but still require limited AHJ or utility review. Where accepted by the relevant authorities, it may also cover a modification to an approved installation that retains the inverter, connection point, and operating mode, provided that capacity, protection, wiring, settings, and certification conditions remain within the approved limits. Retaining those three features alone does not establish eligibility. This pathway may be appropriate where a new dedicated circuit or receptacle must be installed, where export control commissioning must be verified, where the site has not previously been prequalified, or where the AHJ requires inspection of the connection point. Eligibility for expedited review should require, at a minimum:

- an approved product compliance package;
- documented IEEE 1547 and UL 1741 interconnection functions;
- defined touch-safety protection for accessible output conductors or plug contacts;
- appropriate overcurrent and ground-fault protection;
- documentation that relevant circuit components are suitable for bidirectional current flow where applicable;
- a standardized connection interface, dedicated circuit, or other approved protected connection point;
- installation consistent with manufacturer instructions;
- a simplified one-line diagram and site information;
- the proposed PV, storage, EV charging, and any power export or backup functions are within the scope and conditions of the accepted system evaluation; where included, storage classification and applicable installation conditions are accepted under the pathway;
- utility notification, registration, or approval of the operating mode; and
- export control or PCS documentation if used.

For qualifying systems, the AHJ review may be limited to verification of site-specific circuit and installation conditions. The utility review may similarly be limited to a standardized technical screen addressing system capacity, export mode, service configuration, metering, and potential distribution system impacts. The expedited review package may include:

- equipment specifications and certification documentation;
- maximum AC output rating and operating mode;
- simplified one-line diagram;
- branch circuit rating, conductor ampacity, and receptacle or connection-point information;
- GFCI and overcurrent protection documentation;
- grounding and bonding information;
- disconnecting means and labeling information;

- export control or PCS settings, commissioning procedure, and failure response if applicable;
- installation photographs or inspection checklist where required; and
- utility registration or interconnection application information.

The goal of Pathway 2 is not to eliminate AHJ or utility oversight, but to make review predictable, repeatable, and faster than a conventional DER permit for standardized, lower-risk MEGA®-type deployments.

5.3.3 Pathway 3: Full Interconnection and Permitting Review

The full review pathway is the default pathway for systems that do not satisfy the eligibility criteria for notification-only or expedited review. This pathway may be appropriate when:

- the equipment is not certified or evaluated to applicable standards;
- the complete system configuration has not been evaluated;
- the installation uses a nonstandard electrical configuration;
- the proposed export mode has not been accepted under a streamlined pathway or requires site-specific utility review;
- the connection is made to a non-dedicated circuit without evaluated overload mitigation;
- bidirectional GFCI or overcurrent protection suitability is not documented;
- the deployment is located at a critical facility;
- the site presents unusual electrical, service, metering, or distribution-system conditions; or
- the utility or AHJ determines that site-specific review is required.

Under this pathway, the applicant should submit the applicable product documentation, site electrical information, detailed one-line diagram, circuit and protection information, grounding and bonding details, disconnecting means, labeling, operating mode, export control documentation if applicable, and interconnection application required by the serving utility and AHJ. The utility and AHJ would independently evaluate the application within their respective authorities.

Full review does not guarantee approval or cure missing certification, an excluded operating mode, or an unacceptable installation. Pathway 3 is not intended as a penalty pathway. Rather, it is the appropriate process for installations where site conditions, operating mode, protection strategy, or utility impacts cannot be verified through a standardized checklist.

Table 4 summarizes the proposed three-tier approval framework. Figure 3 shows the flowchart for the proposed permitting decision.

Table 4: Proposed Three-Tier Approval Framework for MEGA®-Type Plug-In PV Appliances

Pathway	Use case	Eligibility basis	Review process
Pathway 1: Notification only	Prequalified deployments using an approved product configuration, approved connection point, and approved operating mode. Intended as a future or jurisdiction adopted pathway for highly standardized lower-risk deployments.	Complete system evaluation or listing; applicable IEEE 1547/UL 1741 compliance; documented touch-safety protection; prequalified dedicated 240 V circuit, dedicated PIPV receptacle, or other approved protected connection point; documented bidirectional protection where applicable; an operating mode accepted under the utility's adopted pathway, including any applicable non-export or limited-export controls; no new field wiring or site-specific engineering.	Customer or qualified installer submits standardized notification identifying equipment, serial number, address, maximum AC output, connection configuration, operating mode, and compliance declarations. No project-specific engineering review unless the submission fails an eligibility screen or the AHJ/utility identifies site-specific concerns.
Pathway 2: Expedited review	Standardized deployments that meet defined technical criteria but require limited AHJ inspection, utility screening, installation verification, or export control commissioning.	Approved product compliance package; documented interconnection functions; defined touch-safety protection; appropriate overcurrent and ground-fault protection; documented suitability for bidirectional current flow where applicable; standardized connection interface or dedicated circuit; simplified one-line diagram; installation consistent with manufacturer instructions.	AHJ review focuses on site-specific circuit and installation conditions. Utility review uses a standardized screen addressing system size, export mode, service configuration, metering, and distribution-system impacts. Projects are escalated to full review if nonstandard conditions are identified.

Table 4: Proposed Three-Tier Approval Framework for MEGA®-Type Plug-In PV Appliances, continued

Pathway	Use case	Eligibility basis	Review process
Pathway 3: Full review	Default pathway for systems that do not qualify for notification-only or expedited treatment, including nonstandard, incompletely evaluated, or site-specific installations. Export capability alone does not preclude streamlined review of an accepted configuration.	Applies where certification is incomplete, the complete system has not been evaluated, the installation is nonstandard, export control is not approved, bidirectional protection is not documented, the site has unusual electrical or distribution conditions, or the AHJ/utility requires project-specific review.	Applicant submits a complete permitting and interconnection package. AHJ performs standard electrical permit review, and utility performs applicable interconnection review. This pathway remains appropriate until standardized eligibility criteria are satisfied.

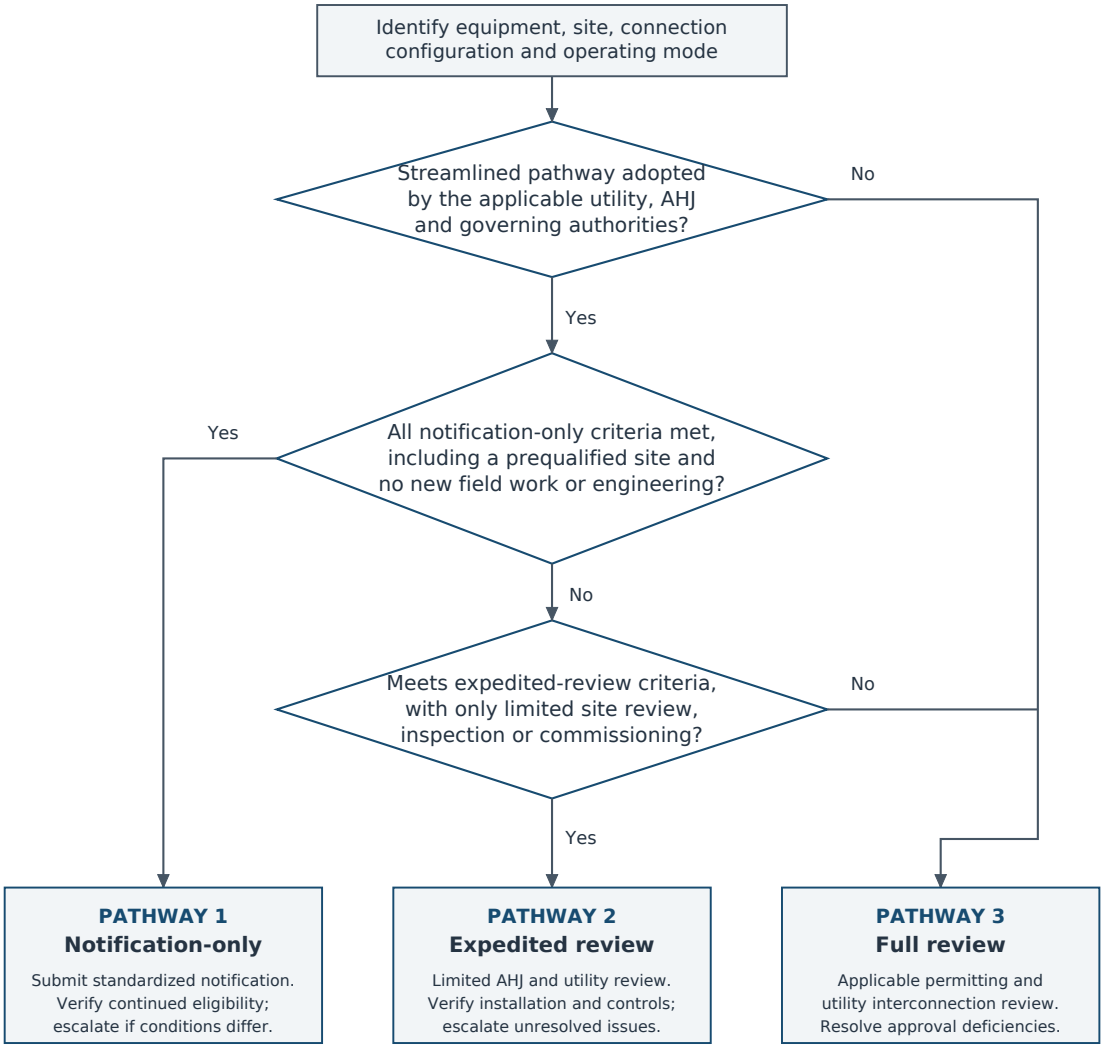


Figure 3: Proposed permitting decision flowchart.

5.4 Suggested Export Control Verification Profile

For plug-in PV appliances that rely on non-export or limited-export operation, utilities may need evidence that export limits are enforced under normal operation and credible failure conditions. UL 3141 provides a relevant evaluation framework for PCS functions, including power export limiting, when such functions are within the scope of the equipment evaluation. UL Solutions describes testing under changing load and generation conditions, as well as loss-of-control testing involving sensing signals, required communications, and control circuit power [21].

Table 5 provides an example verification profile that can be used to document export control performance for utility review. This profile is suggested guidance for equipment-specific verification; it does not establish certification requirements or replace applicable standards, utility interconnection procedures, manufacturer instructions, or the functions covered by the equipment's certification.

The test plan should distinguish product-level evaluation from site commissioning and identify the responsible testing or commissioning party. Existing certification test evidence may be credited where it covers the same function, configuration, and acceptance criteria. Fault simulation may require controlled laboratory conditions. Site commissioning should verify installation-specific sensing, polarity, settings, communications, and export behavior using applicable manufacturer and utility procedures. Additional tests should be limited to those needed to verify the installed configuration and requirements.

Before testing, the test plan should identify the approved export limit, measurement tolerance, permitted transient export magnitude and duration, maximum control response time, and maximum time to reach the defined fail-safe state. If no transient export is allowed, the acceptance criteria should state that restriction. Response-time measurements should distinguish fault detection, entry into the fail-safe state, and return of export to the permitted range.

Table 5: Example export control verification profile for a 240 V plug-in PV appliance.

Test item	**Suggested verification**	**Performance to document**
Configuration and steady-state operation	Verify current transformer (CT), current sensor, or meter placement, polarity, export settings, and required communications. Vary PV output and local load.	Export measured at the point of common coupling (PCC) remains within the approved limit and agreed measurement tolerance.
Rapid source/load changes	Test rapid generation increases and, at high PV output, rapid load reduction or EV charging disconnection. Where applicable, test with storage full, unavailable, or discharging.	Document peak export, duration above the approved limit, and time to return to the permitted range. Results satisfy the applicable acceptance criteria.

Table 5: Example export control verification profile for a 240 V plug-in PV appliance, continued

Test item	Suggested verification	Performance to document
Loss of sensing or metering input	Verify sensor polarity during commissioning. Safely simulate missing, invalid, or out-of-range inputs and assess plausible misconfiguration using manufacturer-approved procedures.	Detectable faults trigger the documented fail-safe response within the applicable time limit. Verify export against the permitted transient allowance; document misconfiguration that requires commissioning checks rather than automatic detection.
Loss of required communications or control power	Separately interrupt each communication link needed for export enforcement and simulate loss of control-circuit power using manufacturer-approved or laboratory procedures.	The system curtails or disconnects generation, or uses another verified fallback mode that maintains the approved export constraints within the documented time and transient limits.
Protection against unauthorized changes	Attempt unauthorized setting changes and verify settings after power cycling. Evaluate foreseeable bypass or misconfiguration of sensing or control functions.	Export-limit enforcement remains effective, or the system enters a fail-safe state. Alarms or event logs alone do not demonstrate enforcement.
Recovery after a fault	Restore sensing, communications, or control power after a fail-safe event.	Normal operation resumes only after valid measurements, required control functions, and approved export settings are confirmed.

Verification should use independent measurements at the PCC with sufficient accuracy and time resolution to capture export excursions. The report should identify the measurement boundary, averaging interval, equipment and firmware versions, approved settings, test conditions, peak export, duration above the approved limit, and response times measured from the initiating disturbance or fault. Results should be compared with the applicable acceptance criteria.

Fault simulation should follow manufacturer-approved safety procedures; some tests may require laboratory evaluation rather than field commissioning. Export control verification does not establish compliance with connector safety, ground-fault protection, battery

safety, or operating mode requirements, and it does not authorize an export function that is excluded by the applicable product evaluation. The test plan should also specify whether the export criterion applies to aggregate net power or to individual phases, and should identify the measurement sign convention.

5.5 Implementation Considerations

Implementation of this framework would require coordination among manufacturers, testing laboratories, AHJs, utilities, and other governing authorities, with standards development bodies involved where clarification or revisions are needed. A practical program could begin with controlled pilot installations reviewed under Pathway 2 or Pathway 3. Experience from these installations could inform future notification-only procedures, including capacity and export screening, storage classification, panelboard checks, and metering verification. Use of Pathway 1 would remain conditional on authorization by the applicable authorities and verification that the equipment, installation, operating mode, and site satisfy the adopted eligibility criteria.

If enacted as introduced, H.R. 10851 would require covered state regulatory authorities to commence consideration or set a hearing date within one year and make a determination within two years, subject to its prior-state-action provisions [8]. Such proceedings could provide a forum for discussing streamlined treatment of the bill's defined 120 V device class. They would not automatically adopt this paper's framework or extend it to 240 V appliances. Whether an existing state proceeding would satisfy the proposed prior-action provisions would require a separate assessment; no such finding is made here.

A standardized MEGA® permitting and interconnection package should include, as applicable:

- complete system listing or evaluation documentation, including configuration limits and conditions of use;
- evidence of applicable IEEE 1547 conformance and UL 1741 certification for the inverter and interconnection equipment;
- PIPV system-level evaluation documentation where applicable;
- touch-safety and connector documentation;
- branch-circuit, receptacle, grounding, and bonding requirements;
- panelboard loading documentation accounting for all power sources, and an inventory of existing generation and storage at the service;
- the service metering configuration and evidence of compatibility with the accepted operating mode;
- identification and ratings of evaluated GFCI and overcurrent protective devices;
- operating mode descriptions, including applicable storage, EV charging, power export, and stand-alone functions;

- export control or PCS documentation, including settings, sensing arrangements, failure behavior, and verification procedures;
- installation instructions, labeling, disconnecting-means information, and required emergency-response information;
- procedures for verifying location specific settings and completing any required commissioning following relocation;
- owner instructions for relocation, notification, registration, and any required renewed approval; and
- an AHJ/utility checklist identifying required documentation, responsible parties, and criteria for additional review.

This approach could support consistent review and reduce unnecessary procedural burden for qualifying deployments while maintaining applicable safety, installation, utility interconnection, and grid-visibility requirements.

6.0 Conclusion

Plug-in photovoltaic systems have the potential to expand access to distributed solar generation by enabling consumer-deployable, appliance-class PV products for customers who may not be able to install conventional rooftop PV. European experience, particularly with German balcony PV, demonstrates that simplified deployment can occur when technical requirements, product certification, registration, metering, and utility processes are clearly defined. In the United States, however, plug-in PV deployment remains constrained by fragmented interconnection rules, uncertain NEC interpretation, inconsistent AHJ and utility treatment, and the lack of a widely adopted permitting pathway for mobile or appliance-class DERs.

This paper reviewed the principal technical and regulatory requirements relevant to MEGA®-type 240 V plug-in PV appliances, including IEEE 1547, IEEE 1547.1, UL 1741, UL 3700, UL 3141, UL 943, and the NEC. The review shows that no single standard or code provision resolves all issues associated with medium-size plug-in PV deployment. The paper discusses three principal safety issues: touch safety, breaker masking and branch-circuit overload, and bidirectional GFCI protection, and identifies potential mitigation measures for each.

A risk-informed permitting framework for MEGA®-type deployments is proposed in this paper. The framework distinguishes among three pathways: notification-only deployment for future prequalified and highly standardized systems; expedited interconnection and permitting review for standardized installations requiring limited verification; and full interconnection and permitting review for installations that do not meet the adopted streamlined eligibility criteria. Export capability alone does not preclude streamlined review of an accepted configuration, and full review does not guarantee approval. This approach preserves AHJ and utility authority while reducing unnecessary procedural burden for lower-risk deployments that meet predefined technical and documentation criteria.

The proposed framework should be understood as a pathway for structured review rather than as a conclusion that all MEGA®-type systems are presently eligible for notification-only treatment. In practice, implementation will require coordination among manufacturers, NRTLs, AHJs, utilities, state regulators, and code-making bodies. A practical next step is to develop a standardized compliance package that includes product certification evidence, inverter IEEE 1547/UL 1741 documentation, applicable PIPV system-level evaluation, touch-safety test results, branch-circuit and receptacle requirements, GFCI and overcurrent protection documentation, export control or PCS information, installation instructions, labeling, relocation instructions, and AHJ/utility checklists.

With clear product evaluation, standardized documentation, dedicated or otherwise protected connection points, and utility registration, MEGA®-type plug-in PV appliances could be reviewed more consistently and efficiently than under conventional DER interconnection procedures alone. Such a framework would support safe innovation in consumer-deployable solar while maintaining the core safety, code-compliance, and grid reliability functions required by AHJs and utilities.

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