

Utility-Interconnected Photovoltaic Systems: Evaluating the Rationale for the Utility-Accessible External Disconnect Switch

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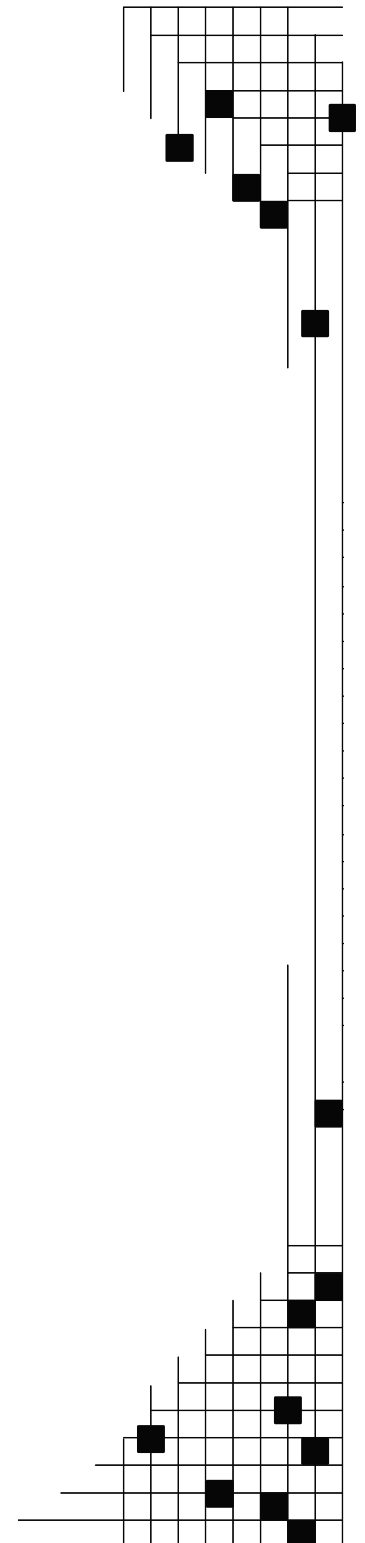
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List of Acronyms

AC	alternating current
EDS	external disconnect switch
IEEE	The Institute of Electrical and Electronics Engineers
NEC	National Electrical Code
NESC	National Electrical Safety Code
PG&E	Pacific Gas and Electric
PUC	public utility commission
PV	photovoltaic
SMUD	Sacramento Municipal Utility District
UL	Underwriters Laboratories

Executive Summary

The utility-accessible alternating current (AC) external disconnect switch (EDS) for distributed generators, including photovoltaic (PV) systems, is a hardware feature that allows a utility's employees to manually disconnect a customer-owned generator from the electricity grid. Proponents of the EDS contend that it is necessary to keep utility line workers safe when they make repairs to the electric distribution system. Opponents assert it is a redundant feature that adds cost without providing tangible benefits.

In this paper, we examine the utility-accessible EDS debate in the context of utility-interactive PV systems for residential and small commercial installations. We also evaluate the rationale for EDS requirements. In particular, we focus on the safety, reliability, and cost implications of the EDS. We observe that in a number of states in which public utility commissions (PUCs) and utilities have gained experience with PV systems, they have decided to eliminate the EDS requirement. These decisions typically require that utility-interactive PV systems use inverters that meet relevant Underwriters Laboratories (UL) and Institute of Electrical and Electronics Engineers (IEEE) standards. We argue that, going forward, a number of factors are likely to convince additional PUCs and utilities to eliminate the EDS requirement. These include demonstrated safety and effectiveness of UL- and IEEE-listed inverters, a need to re-evaluate safety practices and rules in light of technological advances and regulatory changes, a desire to reduce the administrative burden of requiring the EDS, and growing pressure to remove barriers to entry for PV systems.

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1. Introduction

Photovoltaic (PV) systems are a maturing technology. In the United States in 2006, the number of installed PV systems exceeded 30,000, and the number is continuing to grow. This paper focuses on residential and small-commercial PV systems that interconnect with the electricity grid. (See Figure 1.)

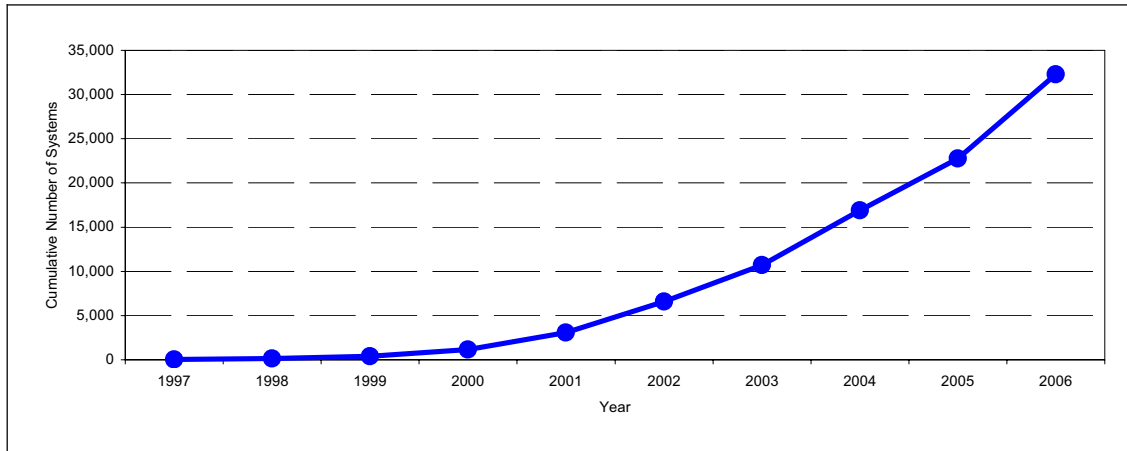


Figure 1. Utility-interactive PV systems installed in the United States, 1997–2006 [1]

Many electric utilities require a customer-owned, utility-accessible external disconnect switch (EDS), often within sight of the revenue meter. This requirement has been an issue of debate among utilities, state public utility commissions (PUCs), and PV system integrators/installers for several decades.

Some people ask: “Why is a utility-accessible EDS necessary? Is it worth the additional cost?” Others ask, “Why take a chance, even if it is remote, with issues of safety and reliability?” Having a utility-accessible EDS for each PV system on a distribution line may allow for maximum safety, but some people question the use of such a device in practical utility operations.

PV systems must meet a variety of codes and standards to be accepted by the local authority having jurisdiction. For example, the National Electrical Code® (NEC) covers all electrical installation requirements on the customer side of the utility revenue meter. Underwriters Laboratories (UL) Standard 1741 [2] covers inverters, which convert direct-current (DC) power to alternating-current (AC) power for use by the customer or utility. The Institute of Electrical and Electronics Engineers (IEEE) Standard 1547™ [3] provides interconnection requirements for PV systems at the point of common coupling and is referenced in the utility connection requirements of UL 1741. In addition, most electric utilities design and operate their electric distribution systems to meet the standards of the National Electrical Safety Code® (NESC), which does not address PV systems directly.

The development of IEEE 1547 and UL 1741 involved varied groups of balloters and contributors (known as working groups). Both standards were developed by groups that included significant utility representation. For example, for IEEE 1547, electric utility representatives comprised 34% of the 230 balloters [4]. UL 1741 also had a significant utility presence in standard development [5].

IEEE 1547, UL 1741, and the NEC do not address the use of customer-owned, utility-accessible EDSs for PV systems. IEEE 1547 does recognize that an EDS is not a universal requirement but that a utility may desire an EDS for its own use. These codes and standards require that PV systems automatically disconnect from the grid in the event of an electric outage. However, many utilities require a redundant utility-accessible EDS in the event of a grid-related problem.

In addition to the utility-accessible EDS, PV systems have several disconnect methods in the event of electric outages, fires, or maintenance. PV systems disconnect from the grid to prevent electricity generated by them from feeding into the grid when a problem occurs on it. Some disconnecting equipment, such as ground fault protection and inverter relays, is automatic. Others—including DC disconnects, inverter DC breakers, inverter AC breakers, EDSs, PV system circuit breakers in customer panels that are backfed, main breakers,¹ utility production meters,² and utility revenue meters—are manual. Although the NEC requires a disconnecting means in a readily accessible location, it does not specify that it be outdoors or accessible to utility personnel [6].

Clearly, if a utility-accessible EDS is required, it makes sense for utilities to integrate its use into their standard practices and procedures. Thus, it is worth examining the implications of using EDSs in utility service territories in which there are significant or growing numbers of PV systems and evaluating whether they are a practical tool for enhancing safety.

Several significant issues are involved. First, as the number of PV systems increases, the work and time needed to troubleshoot an outage on a distribution circuit with PV systems (and EDSs) will increase. Second, if utility line workers are required to use a group of EDSs on a line section, the EDSs must be incorporated into switching orders.³ Third, the geographic information system departments at utilities will need to maintain accurate and timely maps to help dispatchers and line workers locate the EDSs during emergencies. And fourth, if line workers choose to ignore EDS requirements, utilities may face liability in the event of injury or equipment damage and must consider if disciplinary action will be taken.

¹ Not all homes and businesses have a main disconnect.

² Production meters are required by some utilities to track the total energy output of a system.

³ Switching orders are used by utilities to plan and track the de-energization and re-energization of sections of lines and equipment in a safe manner

Pacific Gas and Electric (PG&E) and Sacramento Municipal Utility District (SMUD), both major electric utilities in California, changed their policies for inverter-based PV systems. Their decisions to eliminate utility-accessible EDS requirements for smaller PV systems were based on expected cost and time savings for the utilities and their customers. These utilities have a large and growing number of customer-sited PV systems to consider, and the EDS requirement was delaying installations and multiplying administrative costs.

It is worth noting that PG&E has the most interconnected PV systems in the United States and SMUD has been one of the most aggressive adopters of PV technology in the country. The fact that these utilities have eliminated their EDS requirements is likely indicative of a trend. As other electric utilities gain experience with PV technology and a better understanding of the safety features required by the UL and IEEE standards for PV inverters, they are likely to follow PG&E and SMUD and eliminate their utility-accessible EDS requirements.

2. Safety, Reliability, and Cost: Prime Focal Points for Utilities

Utilities have an “obligation to serve”⁴ in a safe, reliable, and economical manner. The incorporation of utility-accessible EDSs into utility operations has implications for many of the utility’s core considerations.

2.1. Safety

Electric utilities supply a commodity that has inherent danger. Line workers understandably believe that no task is more important than maintaining a safe workplace. In an emergency, all line workers are assigned duties to restore the system as quickly and safely as possible. As they work to restore power, they must be extremely cautious. U.S. electric utilities typically follow the NESC⁵ for safe working practices to establish proper clearances and safeguard persons from hazards in the installation, operation, and maintenance of electric distribution systems.

Line workers must “consider the electric supply equipment and lines to be energized, unless they are positively known to be de-energized.”⁶ If a line worker determines that other sources are feeding the circuit, he must locate and open the source or work the line energized.

2.2. Reliability

There is an increasing demand on utilities and PUCs to reduce outage durations.⁷ Some utilities face significant fines and penalties if they fail to meet standards set by their state PUCs. Public scrutiny is a driving factor as well. Prolonged outages cause repercussions for utility customers, and in turn the utility, which may result in an increase in complaints to PUCs.

Although safety is the highest priority for utility line workers, restoring power quickly and efficiently is also important. Although the presence of a utility-accessible EDS for PV systems on distribution lines may allow increased protection for utility personnel, it can be questioned if the device would be used by the utility, especially in the event of a large system outage.

⁴A public utility's duty to serve has its origins in common law principles. See [8].

⁵The NESC is a publication of IEEE (Accredited Standards Committee C2-2007).

⁶Per the NESC Section 42 420.D “Energized Unknown Conditions.”

⁷Two nationally recognized and published reliability indices are the System Average Interruption Duration Index and the Customer Average Interruption Duration Index. The System Average Interruption Duration Index is an index of the average system outage duration over a 12-month average. The Customer Average Interruption Duration Index is an index of the average outage duration per customer over a 12-month average.

2.3. Cost

Operating a distribution system in a cost-effective manner is a goal for all utilities. There is immense pressure from ratepayers and PUCs to keep costs down and rates reasonable while maintaining safety and reliability. Every procedure that a line worker must complete must be examined carefully, as it will affect the cost of service. The time expended operating a group of EDSs must be scrutinized, and a decision must be made regarding whether to use these devices.

If a utility or PUC requires the installation of an EDS and it is incorporated into the utility's operational procedures, there is a significant cost to the utility and ratepayers. This is true even if the full cost of the EDS equipment is paid for by the PV system owner. Additional utility operational costs translate into higher electricity rates because those expenditures are typically recovered from ratepayers.

Although beyond the scope of this paper, it would also be useful to evaluate the full cost of inspecting, mapping, and using the EDS from the utility perspective to provide a realistic estimate of its effect on rates/tariffs.

3. Integrating Customer Photovoltaics into a Utility Distribution System

Utilities have historically relied on power sources such as coal, water, nuclear energy, oil, and natural gas to generate electricity. Their generation stations tie directly into the utility transmission system, and power is then transported to area substations and distributed over local distribution feeders. (The entire system is commonly referred to as the “grid.”) In the traditional model, power flows in one direction: from the substation to the customer location. The grid was designed to operate safely following this model. Careful supervision and operation helped the utility operate a relatively safe and reliable electricity delivery system.

PV and other distributed generation technologies, however, introduce two-way power flow onto the grid, which raises a number of potential issues for grid operation and maintenance. The UL and IEEE standards were developed to enable distributed generators to operate safely and reliably with the grid.

3.1. Interconnection Standards: UL 1741 and IEEE 1547

UL is a nationally recognized testing laboratory that tests to standards for electrical equipment, primarily to ensure safety of consumer products. The UL listing relevant to EDSs is UL 1741 (2005), Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources. UL 1741 was initially published May 7, 1999, and the latest version includes significant revisions.

UL 1741 applies to inverters, the devices that convert the DC electricity output from solar PV cells into AC, which is used in homes and businesses. Based on IEEE 1547 requirements, UL-listed inverters for PV systems require the inverter to disconnect automatically from the grid.

3.2. Modern Electronic Inverters

Modern small-commercial and residential PV systems include UL-listed components that meet rigorous standards. Inverter technology has advanced considerably in the past decade, and new inverters are required to meet the stringent standards of UL 1741 and IEEE 1547. The NEC requires that an inverter de-energize its output upon loss of utility voltage and remain in that state until utility voltage has been restored [6]. Modern electronic inverters are reliable, intelligent, and comprehensively tested to ensure they do not backfeed to the grid during an outage.

Modern electronic inverters used in PV systems must meet UL 1741 standards to be “listed and labeled.” UL 1741 incorporates IEEE 1547 requirements and IEEE 1547.1 [7] procedures for utility-interactive inverters. The NEC also requires that the system “shall automatically de-energize its output to the connected electrical production and distribution network upon loss of voltage in that system and shall remain in that state until the electrical protection and distribution network voltage has been restored” [6]. Numerous independent laboratories, including the National Renewable Energy Laboratory and Sandia National Laboratories, have tested and evaluated a variety of PV components and found that UL-listed inverters perform reliably, as specified.

In the case of an emergency when the grid is down, UL-listed inverters sense a situation known as “islanding”⁸ and automatically disconnect if the utility source is absent. Under all abnormal or grid-outage conditions, a UL-listed inverter disconnects in 2 seconds or less and only reconnects after 5 minutes of normal utility conditions.

A manual utility-accessible EDS will require line workers to travel to homes and other buildings with utility-interactive PV systems and manually open the switches. In terms of response, a UL-listed inverter is obviously much faster because it disconnects from the grid quickly and without the need of human intervention.

⁸ In this situation, islanding is unintentional. Islanding is a condition in which a portion of an area electric power system is energized by one or more local electric power systems while separated from the rest of the area electric power system. See [3] for additional information about islanding.

4. Defined Purpose of a Utility-Accessible External Disconnect Switch

The purpose of the utility-accessible EDS, from the utility perspective, is to enable line workers to lock out a customer source of power that could feed back onto the grid while utility line workers are working. In this context, a utility-accessible EDS could be used:

- When there is a specific customer-based problem and the utility wants to isolate that customer from the grid
- During the installation phase of new construction
- When line workers are replacing aged or damaged equipment on the utility's system
- During an unplanned electric outage (i.e., a “trouble” situation).



Figure 2. A typical residential PV installation includes (1) an EDS, (2) a DC disconnect, (3) an Inverter (with AC and DC breakers shown in the red circle), and (4) a revenue meter

Photo courtesy of Nicholas Lenssen.

Figure 2 illustrates the variety of equipment that could isolate the PV system from the utility grid. As shown, a typical PV installation has four options for a line worker to disconnect the system (in addition to the EDS). This is an example of a system with most of the system equipment installed outdoors, but some systems include equipment that is mounted indoors.

There are several means of disconnecting power in a typical PV system. The NEC requires (with some exceptions) that most systems have ground fault protection on the DC side of the inverter. The NEC also requires that the system have a means of disconnecting the system on the DC side of the inverter and the AC side of the utility-interactive inverter. In addition, the NEC states that a “disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the system conductors.” Ungrounded conductors may be disconnected by either a switch or circuit breaker, per the NEC [6].

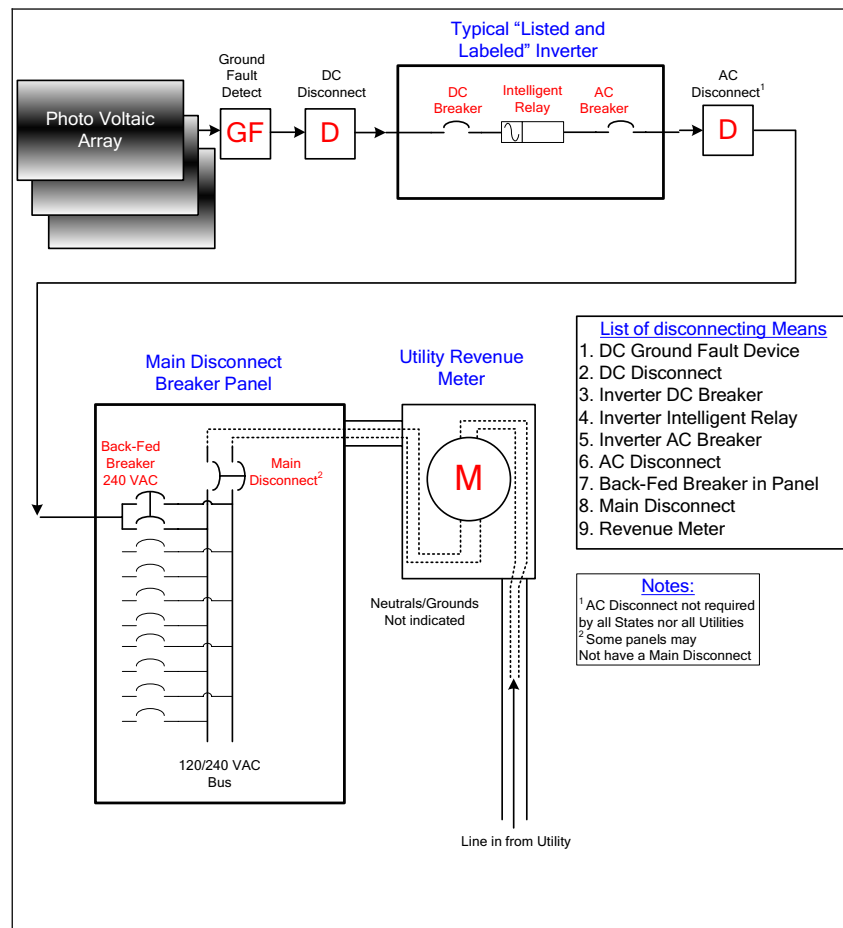


Figure 3. Typical residential/small commercial PV system schematic

It is important to note that there are at least six manual and automatic disconnect devices in a PV system. In Figure 3, there are nine means of disconnecting the PV system from the grid:

- Ground fault protection at or near the PV array⁹
- The DC disconnect switch between the PV array and the inverter
- The inverter DC breaker
- The inverter relay (This is an automatic device that disconnects the inverter if UL 1741 conditions are not met.)
- The inverter AC breaker
- The AC EDS
- The backfed circuit breaker (on the customer panel)
- The main disconnect (Not all buildings have a main disconnect.)
- The utility revenue meter (This historically has been used by utilities as a means of disconnecting customers for a variety of needs.).

Although the NEC contains specific requirements for a readily accessible disconnect switch, it does not require that it be installed outdoors.

⁹ NEC-2008 690.5 “Ground Fault Protection” states requirements for ground fault protection.

5. Utility Line Practices

5.1. New Construction

New construction, whether it is overhead or underground, is usually performed while equipment is de-energized. Because there is a risk that a line could be energized during installation, equipment is grounded as a matter of procedure. Line workers are required to test and ground the line before they begin work to ensure they do not contact a live line and risk injury or death [9].

5.2. Customer-Related Problems

It is essential that utilities have the ability to isolate sources of problems on their systems, whether they are at the generation, transmission, or distribution level or a customer location. In normal business practice, if a utility worker believes there is a problem behind a customer's meter, the utility contacts the customer to resolve the problem. Only in unusual situations will utility personnel disconnect a customer by using the main disconnect or removing the revenue meter.

5.3. Trouble Situations

Utility line workers typically consider a line to be energized while working a "trouble" situation. This requires that they wear Occupational Safety and Health Administration- and American National Standards Institute-approved protective equipment, such as rubber gloves, fireproof clothing, eye protection, and insulated tools. Because all lines are considered energized during an outage, an EDS should not be necessary.

Utilities are aware that a small generator could be attached to a customer's service and, in error, create backfeed that places line workers in danger. But if a line crew works on an energized feeder, it will avoid injury if the proper procedures are followed. Similarly, when a crew works a line cold, the appropriate ground cables are installed, and the line is tested, it will avoid injury if the proper procedures are followed.

In the event of a feeder outage, a line crew will risk injury from a PV system only if *all* of the following events occur:

1. The inverter fails to disconnect automatically and somehow produces power without the necessary external voltage source present
2. The anti-islanding, voltage, and frequency methods fail in the inverter
3. The load at the output of the inverter matches the connected load of the PV owner and adjacent customers (This is statistically improbable.)
4. The line worker chooses to work the line energized but fails to follow procedures or;
5. The line worker chooses to work the line de-energized but fails to test and ground the line.

Therefore, a very unlikely series of events must occur to place a line worker at risk from a PV system installed without an EDS.

5.4. Normal Restoration of Outages and the Time Factor

In the event of an electric power outage, a utility will dispatch a line worker to:

- Troubleshoot the outage
- Clear the line or cause of outage
- Repair any damage
- Ensure the area that was damaged is now safe
- Restore power.

This process is expected to be completed as quickly as possible to restore power to affected customers. Average electric outage duration times in the United States are often under 2 hours.¹⁰ However, keeping outage duration at less than 2 hours would be a commendable achievement if line workers had to visit each EDS on a feeder.

Because line workers are expected to troubleshoot and restore electric outages quickly, and because the restoration work is accomplished under the presumption that the lines are energized, it is unlikely that a line worker would use an EDS unless required to do so by documented utility switching procedures.

¹⁰ Based on published utility reliability data. For a detailed explanation of reliability indices and published data, see report by LaCommare, K.H.; Eto, J.H. *Understanding the Cost of Power Interruptions to U.S. Electricity Consumers.* LBNL-55718. Berkeley, CA: Ernest Orlando Berkeley National Laboratory, September 2004. Available at <http://certs.lbl.gov/pdf/55718.pdf>.

6. Work Practice Integration

When a utility requires a PV system owner to install an EDS, it must establish how the device will be incorporated into standard procedure. For example, if the EDS is tracked, will the utility use its customer information system and geographic information system, and will dispatchers use that information to resolve outages and write switching orders? If a line worker ignores the EDS installation, will the line worker or the utility face punitive damages or disciplinary action?

6.1. Prompt Restoration of Service Imperative

When a utility's distribution network is down, the utility is under intense pressure to restore power to customers as quickly as possible. Yet, if the utility relies on EDSs as part of its safety protocol, then its line workers must use these switches in an emergency or repair to the distribution network. Thus, the line workers must travel to each location with a utility-accessible EDS to lock the switch in the open position before starting repairs. After the repairs have been completed, the line workers must travel to each location and manually close the switch (to restore PV power to that customer). This would add considerable time to the process of restoring power to the grid.

In addition, such emergencies may take place under severe weather conditions, such as freezing rain, high winds, or flooding. Requiring line workers to navigate these conditions to travel to each location may pose additional risk to their safety. They could lose control of a vehicle while driving on ice, be forced to navigate flood waters, or have to contend with fallen tree limbs.

6.2. Other Sources of Power

Line workers must consider a line energized unless it is positively known to be de-energized, per Rule 420 of the NESC [9]. This critical rule takes into consideration that customers may have gas-powered generators tied to their home and businesses. All building supply stores sell gasoline-powered electrical generators and the electrical equipment necessary to properly isolate and power a home or business. However, because it is not mandatory that these systems be registered with the utility—and they are often not inspected by the appropriate authority having jurisdiction—utility line workers must assume they are energized during an electric outage. These generators are designed for standalone use, but they are simple to interconnect without provisions to avert backfeed into the grid.

7. Relative Cost of a Customer-Owned External Disconnect Switch

The installation of a utility-accessible EDS for PV systems has been a contentious issue for several years. Although some utilities and PUCs require an EDS for PV systems, most PV system installers and owners view the EDS as unnecessary in the era of modern inverter-based interconnection. For PUCs, the decision to require—or allow a utility to require—a utility-accessible EDS is a matter of balancing safety, reliability, and cost (to the utility, rate payers, and the PV system owner).

The cost of an EDS, which is typically several hundred dollars, is not insignificant to PV system owners. It is a particularly unwarranted cost if EDSs are required but not incorporated into utility operating procedures. If a utility requires its customers to install utility-accessible EDSs, it should incorporate the devices into its working rules and operations as practical procedure. Further, if EDSs are required for customer-owned PV systems, the utility should validate any problems with customer-owned systems and determine whether the EDSs are beneficial and thus justify their cost.

An illustrative case is documented in a study conducted by Cassandra Kling, a leader in the New Jersey Million Solar Roof Partnership and renewable energy program manager for the New Jersey Board of Public Utilities at the time, and Christopher Cook, a consultant [10]. Kling and Cook found that none of the EDSs studied had been used by utility maintenance staff. Furthermore, despite their lack of use, no safety incidents had been reported.

8. Review of Past Utility Commission Decisions Regarding External Disconnect Switches

The Energy Policy Act of 2005 calls for state PUCs (and various “non-regulated” utilities) to consider adopting certain standards for electric utilities. Under Section 1254 of the act, “Interconnection services shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547” and “shall be established whereby the services offered shall promote current best practices in interconnection” [11].

Because Federal Energy Regulatory Commission Order 2006 [12] for the interconnection of distributed generators does not require EDSs, there is no federal policy governing this issue. If a state elects to set policy on interconnection, it usually delegates the authority to create rules to the PUC or similar authority. Each state’s PUC has the option to create its own rules.

Some states have ruled that inverter-based interconnections do not need EDSs, while others have ruled that inverter-based interconnections must have utility-accessible EDSs. And finally, some states leave the decision to the electric utilities, which often take the most conservative approach and require EDSs.

8.1. States’ Stands on External Disconnect Switches

In the United States, 35 states have interconnection rules for distributed generation systems such as the inverter-based PV systems discussed in this paper. Among these states, 18 require an EDS for all systems, 8 specifically waive the requirement for small systems (that meet specific technical requirements), and 9 leave the decision to utilities. Table 1 provides a detailed overview of interconnection rules by state.

Table 1. Interconnect Requirements by State

State	Year	Comments
Alabama	NA	No state rules in effect
Alaska	NA	No state rules in effect
Arizona	2007	No state EDS requirement; utility discretion http://www.azcc.gov/utility/electric/dg.htm
Arkansas	2007	No EDS required for systems that meet conditions (see link) http://www.apscservices.info/rules/net_metering_rules.pdf
California*	2000	No state EDS requirement; utility discretion (SMUD and PG&E have waived the requirement for systems with self-contained meters that meet IEEE 1547, UL 1741, and NEC.) http://www.energy.ca.gov/distgen/interconnection/california_requirements.html

State	Year	Comments
Colorado	2005	No state EDS requirement; Utility discretion http://www.leg.state.co.us/clics/clics2007a/csl.nsf/fsbillcont3
Connecticut	2004	EDS required http://www.dsireusa.org/documents/Incentives/CT06R.doc
Delaware	2000	No EDS required for systems <25 kW http://dep.sc.delaware.gov/orders/6983.pdf
Florida	2002	No EDS required for systems ≤10 kW http://www.psc.state.fl.us/agendas/archive/071218cc/071218.html
Georgia	2001	No state EDS requirement; utility discretion http://www.dsireusa.org/documents/Incentives/GA04R.htm
Hawaii	2002	EDS required http://www.dsireusa.org/documents/Incentives/HI01Rc.pdf
Idaho	NA	No state rules in effect
Illinois	NA	No state rules in effect (Com Ed has decided that EDSs are not required for systems <40 kW.)
Indiana	2005	No state EDS requirement; utility discretion http://www.in.gov/legislative/iac/iac_title?iact=170&iaca=4
Iowa	2007	EDS required http://www.legis.state.ia.us/Rules/Current/iac/199iac/19915/19915.pdf
Kansas	NA	No state rules in effect
Kentucky	NA	No state rules in effect
Louisiana	2005	EDS required; utility may waive the requirement http://www.dsireusa.org/documents/Incentives/LA03Rb.pdf
Maine	NA	No state rules in effect
Maryland	2007	No EDS required for systems that meet IEEE, UL, and NEC http://mlis.state.md.us/2007RS/chapters_noln/Ch_119_sb0595E.pdf
Massachusetts	2006	No state EDS requirement; utility discretion http://masstech.org/DG/02-38-C_Attachment-B_Tariff-Recs_Clean_June-30-2006.pdf
Michigan	2003	EDS required http://www.michigan.gov/mpsc/0,1607,7-159-16377_43420---,00.html
Minnesota	2004	EDS required http://www.puc.state.mn.us/docs/orders/04-0131.pdf
Mississippi	NA	No state rules in effect

State	Year	Comments
Missouri	2007	EDS required http://www.sos.mo.gov/adrules/csr/current/4csr/4c240-20.pdf
Montana	1999	No state EDS requirement; utility discretion http://www.deq.state.mt.us/energy/Renewable/NetMeterRenew.asp
Nebraska	NA	No state rules in effect
Nevada	2003	No EDS required for systems <10 kW that meet IEEE, UL, and NEC http://www.leg.state.nv.us/Nrs/NRS-704.html#NRS704Sec774
New Hampshire	2001	No EDS required for systems <10 kW http://www.puc.state.nh.us/Regulatory/Rules/puc900.pdf
New Jersey	2004	No EDS required for systems <2 MW http://www.dsireusa.org/documents/Incentives/NJ11R2.htm
New Mexico	2007	EDS required; utilities may allow meter to serve as EDS http://www.nmcpr.state.nm.us/NMAC/parts/title17/17.009.0570.htm
New York	2004	EDS required http://www.dsireusa.org/documents/Incentives/NY02Rc.pdf
North Carolina	2005	EDS required http://www.dsireusa.org/documents/Incentives/NC04Rb.pdf
North Dakota	NA	No state rules in effect
Ohio	2007	EDS required http://dis.puc.state.oh.us/TiffToPDF/A1001001A07C28B45049D31500.pdf
Oklahoma	NA	No state rules in effect
Oregon	2007	No state EDS requirement; utility discretion http://apps.puc.state.or.us/orders/2007ords/07-319.pdf
Pennsylvania	2006	EDS required (can be inside and accessed using a lock box) http://www.dsireusa.org/documents/Incentives/PA07Rb.doc
Rhode Island	NA	No state rules in effect (Narragansett Electric does not require EDSs.)
South Carolina	2006	EDS required http://www.dsireusa.org/documents/Incentives/SC05R.pdf
South Dakota	NA	No state rules in effect
Tennessee	NA	No state rules in effect
Texas	2007	EDS required http://www.puc.state.tx.us/rules/subrules/electric/25.211/25.211ei.cfm

State	Year	Comments
Utah	2002	No EDS required (unless the public service commission deems it necessary) http://le.utah.gov/~code/TITLE54/54_11.htm
Vermont	2006	EDS required http://www.state.vt.us/psb/rules/OfficialAdoptedRules/5500_Electric_Generation_Interconnection_Procedures.pdf
Virginia	2000	No state EDS requirement; utility discretion http://leg1.state.va.us/cgi-bin/legp504.exe?000+reg+20VAC5-315-40
Washington	2006	EDS required; utilities may waive the requirement http://www.wutc.wa.gov/energy
West Virginia	NA	No state rules in effect
Wisconsin	2004	EDS required http://www.legis.state.wi.us/rsb/code/psc/psc119.pdf
Wyoming	2001	EDS required http://legisweb.state.wy.us/statutes/statutes.aspx?file=titles/Title37/T37CH16.htm
Washington DC	2003	No jurisdictional EDS requirement; utility discretion http://dceo.dc.gov/dceo/cwp/view,a,3,q,601821.asp

*California does not require EDSs for very small systems (<1 kW). Because most utility-interactive PV systems are larger than 1 kW, the EDS requirement for PV systems is left to utility discretion, for all practical purposes.

Source: Database of State Incentives for Renewable Energy (www.dsireusa.org), accessed during December 2007. Additional information was collected from state utility commission Web sites and utility Web sites.

The following summarizes the status of the EDS issue in select states:

- Arkansas**
 The Arkansas Public Service Commission decided in 2002 that a “redundant visible, manual, lockable disconnect switch” was not required for customers that meet the IEEE 1547 standard, have installed the system properly, and operate the system as designed. Commission staff and each utility present asked for the switch, but the commission ruled the IEEE requirements were sufficient [13].
- Colorado**
 Colorado passed HB07-1169 in 2007 and left the decision of utility-accessible EDSs up to the utilities. (This applies to investor-owned utilities, municipal utilities, and cooperatives). The largest utility in the state, Xcel Energy, requires EDSs for systems of all sizes.

- **Delaware**
Delaware enacted a rule in July 2007 that allows inverter-based systems of 25 kW or less to be exempt from utility-accessible EDS requirements:

All inverter-based systems with a generating capacity of 25 kilowatts (kW) or less must comply with IEEE 1547 and UL 1741, in addition to Delmarva's technical guidelines. These installations are exempt from the pre-interconnection study. Furthermore, an EDS is not required for smaller inverter-based systems. (In emergencies, the utility reserves the right to disconnect the system without notification.) The customer accepts full responsibility for any risks involved with disconnecting the system” [14].
- **Florida**
On Dec. 7, 2007, the Florida Public Service Commission ruled that inverter-based systems 10 kW or smaller are not required to have an EDS installed if they meet IEEE 1547 and UL 1741 requirements. However, if a utility insists on an EDS, the utility must pay for the full cost of the EDS. Systems larger than 10 kW are required to have an EDS.
- **Nevada**
The Nevada PUC ruled in 2003 that if IEEE, NEC, and UL requirements are followed, the utility may not require additional devices such as an EDS. The commission’s rule states that a “utility is prohibited from requiring certain customer generators to meet additional requirements” [15]. If customers abide by IEEE 1547, UL 1741, and NEC requirements, no additional controls, tests, or insurance are required.
- **New Jersey**
In New Jersey, utilities contended that EDSs should be required for safety. The New Jersey Board of Public Utilities took great interest in the issue and invited several line workers to testify [16]. When asked if they had ever used an EDS, not one line worker said yes. Although utilities in New Jersey advocated for required EDSs, the board ruled against the requirement.
- **Virginia**
The Virginia State Corporation Commission ruled that each electric distribution utility could make its own decision about EDS requirements. The commission ruled that PV systems that meet the NEC, IEEE 1547, and UL 1741 requirements are not required to have any additional safety equipment. However, a utility’s net-metering tariff may require that customer generators include a utility-accessible EDS. The commission provided no criteria to the utilities with which to make the decision [17].

8.2. Forces That Shape External Disconnect Switch Policy

A combination of forces and stakeholders—including utilities, PUCs, solar-focused policies, and the solar industry itself—shape the direction of EDS-related policies.

In the past, PUCs have frequently been closely aligned with utilities with respect to the EDS issue and therefore have required utility-accessible EDSs based on the perceived need for additional safety. However, PUCs and utilities are changing their positions as they become more informed about existing interconnection standards, modern inverters, and real-world experience with utility-interactive PV systems. The accumulation of knowledge from utilities' experiences, such as that of PG&E and SMUD, will likely influence additional PUCs and utilities to consider different policies going forward. Given the pace of the state regulatory process, it is not surprising that standards and technology have evolved more rapidly than regulatory policy in many states.

Another factor that could hasten elimination of the EDS is government support for expanding PV markets. The most prominent example is the California Solar Initiative. Reaching the California Solar Initiative's goal of installing 3 GW of distributed PV systems in California by 2016 will require increasing emphasis on removing barriers to entry for PV at all levels, reducing installed system costs, and improving program administration. All of these pressures point toward removing the EDS requirement. As other states develop initiatives focused on expanding PV markets, whether to meet renewable portfolio standards or other policy purposes, similar pressures will likely emerge.

Finally, the solar industry's stance is that the utility-accessible EDS is redundant, adds unnecessary cost, increases operational complexity, and hampers market deployment of PV. Solar stakeholders argue that modern UL-listed inverters have virtually eliminated risk for utility line workers and that with the more than 30,000 interconnected PV systems in the United States, there has not been a single line worker injury caused by an inverter-based PV system [18]. As the PV industry grows, it will likely begin to play a stronger role in policy debates at the state and federal levels.

8.3. Implications for Utilities

The combination of well-developed standards, improved technology, and market experience is modernizing regulatory and utility policy with respect to the EDS issue. It is providing an open, technical-based, fresh look at decision-making. Over the next 5–10 years, additional utilities and PUCs will likely eliminate their requirements for utility-accessible EDSs for relatively small (i.e., tens to hundreds of kilowatts) utility-interactive PV systems. At least three factors will push utilities in this direction: a desire to streamline business processes, pressure to remove barriers to entry, and a need to re-evaluate safety practices and rules in light of technological and regulatory changes.

Because of the increasing number of interconnections involving distributed PV systems, utilities will need to streamline their interconnection business processes. Although interconnecting a few installations annually requires limited utility resources, as the number of installations grows—from dozens to hundreds and then to thousands annually—the administrative burden and associated costs will increase quickly. Depending on the regulatory arrangement, the additional costs of processing and approving the installation of an EDS may be borne by the customer (increasing the PV system cost) or the utility (increasing electricity rates for all customers). As the number of systems grows, there will be increasing pressure from rate payer interest groups and regulators to reduce or eliminate utility costs associated with the installation and tracking of EDSs in the service territory.

9. Changing Policy Climate

Although many states require utility-accessible EDSs for PV systems, the policy climate may be changing. As previously noted, two major utilities in California—which have significant installed bases of interconnected PV systems—changed their policies by removing their requirements for utility-accessible EDSs for utility-interactive PV systems.

Both Pacific Gas & Electric (PG&E) and Sacramento Municipal Utility District (SMUD) have been pioneers by adopting significant levels of PV generation into their distribution systems for more than a decade. Based on their experience with PV systems, both utilities changed their EDS rules. (See press releases for SMUD [19] and PG&E [20].) In short, they see EDSs as redundant safety features that add cost to PV installations and may act as a barrier to entry for PV systems. In addition, SMUD and PG&E have become confident that the listed and labeled systems operate properly when there are system problems. Finally, and one of the largest benefits of eliminating the EDS for the utilities, was the administrative cost savings realized from the utilities not having to check plans, validate installation locations, and track the devices in customer information systems and geographic information systems.

10. Conclusion

In this paper, we have examined the interplay between evolving technology and standards and changing perceptions of the need for utility-accessible EDSs and related regulations. Although utility arguments for requiring utility-accessible EDSs for grid-connected PV systems may have been justifiable 5 or 10 years ago, today the EDS issue is effectively addressed by UL and IEEE standards.

Going forward, at least four factors are likely to convince additional utilities and PUCs that EDSs are redundant and unnecessary:

- Increasing utility experience with utility-interactive PV systems that demonstrates the effectiveness and safety of UL-listed inverters
- Re-evaluation of safety practices and rules in light of technological advances and regulatory changes
- A desire to reduce or eliminate the administrative burden and associated cost of requiring utility-accessible EDSs
- Growing pressure to remove barriers to entry to meet growing state-level targets for PV installations.

Put simply, the utility-accessible EDS is increasingly viewed as redundant and unnecessary for residential and small-commercial PV systems with UL-listed inverters. Eight state PUCs (i.e., Arkansas, Delaware, Florida, Maryland, Nevada, New Jersey, New Hampshire, and Utah) have reached this conclusion and eliminated their EDS requirements for systems that meet criteria, and nine state PUCs have decided to leave the EDS decision up to individual utilities. In the states with utility choice, at least five utilities have eliminated the EDS requirement. These states and utilities accounted for more than 80% of total installed PV capacity in the United States in 2006.

If states and utilities deem renewable energy systems viable and desirable, then these entities must minimize economic barriers to system deployment while maintaining safe, reliable, and cost-effective utility service. Eliminating the economic and operational burdens of redundant equipment will encourage greater consideration of renewable energy systems by customers. Because many states have aggressive renewable energy goals, they must examine all potential barriers closely and make informed decisions regarding expensive and redundant equipment.

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