REVIEW OF STATE IMPOSED INTERCONNECTION REQUIREMENTS

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ABSTRACT

Interconnection of generation sources to electric utilities raises a host of important and complex technical and safety issues. In order to address these issues, the solar industry, with DOE support, has been a driving force in creating national codes, standards, and recommended practices for utility interconnected PV systems. Other distributed generation industries such as fuel cells have joined in these efforts. These efforts have included substantial input from the majority of the major US inverter manufacturers, a number of utilities, Sandia National Laboratories, Underwriters Laboratories, and a number of other highly respected institutions. National, uniform interconnection standards reduce development and production costs for inverters as well as for PV system installation. Despite the success of these efforts, some states have chosen to add additional interconnection requirements, complicating matters and raising costs. This purpose of this paper is to provide a single, easy to understand reference as to which states have additional requirements, and what those requirements are.

1 INTRODUCTION AND OVERVIEW

It has been the goal of the distributed generation community to have one unified set of guidelines and standards for the entire country. This reduces product development and production costs, increases product reliability through further standardization of manufacturing procedures, and makes it practical to bring in the widest range of expertise. A broad coalition of technical leaders in the distributed generation industry, utilities, and government have worked diligently to assure that the codes, standards, and recommended practices assure safety and power quality for these types of power conversion devices.

For product safety, the industry has worked with Underwriters Laboratories (UL) to develop UL1741, *Standard for Static Inverters and Charge Controllers for use in Photovoltaic Power Systems*. With the recent increase in interest of distributed generation, the scope of UL 1741 was later expanded to include inverters for all types of independent power systems, and the name of UL1741 was changed to *Inverters, Converters, and Controllers for Use in Independent Power Systems*.

With support from Sandia National Laboratories, the PV industry has worked with the Institute of Electrical and Electronic Engineers (IEEE) to develop a national interconnection recommended practice for PV systems, IEEE 929, *Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.*

In order to make a national interconnection standard, the PV industry along with the distributed generation industry and other interested parties have been developing IEEE P1547, *Draft Standard for Interconnecting Distributed Resources with Electric Power Systems*. While IEEE P1547 is still in the draft stage as of this writing, IEEE expects it to be approved as a standard later in 2003.

Other relevant national codes and standards include the National Electric Code; IEEE 519, *Recommended Practices and Requirements for Harmonic Control in Electric Power Systems*; and ANSI/IEEE C62.41, *Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits*. Some states have elected to add additional requirements for inverter manufacturers and installers. In some cases these requirements are contrary to or more stringent than the national codes, standards, and recommended practices.

This paper will review the regulations of all states that have interconnection requirements for PV systems (1). However, it will not include those states that only have power limits for net metering or capacity constraints for net metering. Additionally, this paper will only examine the regulations for installing small PV systems that are the easiest to install from a regulatory standpoint.

2 SAFETY AND PERFORMANCE REQUIREMENTS

Safety in a PV system is of utmost importance to state government regulators and the distributed generation community. There are two parts to the safety of a PV system. The first part deals with safety for the customer who has a PV system installed, and the second part deals with the safety of interconnecting the PV system to a regional electric grid.

TABLE 1: SAFETY AND PERFORMANCE REQUIREMENTS OF VARIOUS STATES

State	NEC	UL	IEEE
AR	Yes	UL1741	IEEE 929
CA	No	UL1741 w/mods	IEEE 929 w/mods IEEE 519
CO	Yes	Yes	Yes
DE	Yes	UL1741	IEEE 929 IEEE 519
FL	No		No
GA	Yes	Yes	Yes
HI	Yes	Yes	Yes
IL	Yes		No
MD	Yes	Yes	Yes
MO	No		No
MT	Yes	Yes	Yes
NV	Yes	Yes	Yes
NH	No	UL1741	IEEE 929
NJ	Yes	UL1741	IEEE 929
NM	Yes	Yes	Yes
NY	No	UL1741	IEEE 929 IEEE 519
OH	No	UL1741	IEEE 929 IEEE 519 w/mods
OR	Yes	Yes	Yes
TX	Yes	Yes w/mods	Yes w/mods
UT	Yes	UL1741	IEEE 929
VT	Yes	UL1741 w/mods	IEEE 929 w/mods
VA	Yes	Yes	No
WA	Yes	Yes	Yes
WY	Yes	Yes	Yes

Safety for the customer is addressed by the National Electric Code (NEC) for system installation, and by UL standard UL1741 *Inverters, Converters, and Controllers for Use in Independent Power Systems* for the inverter itself.

Table 1 shows the 24 states that have interconnection requirements and which safety and performance requirements are specifically called for in their net metering or interconnection regulations. “Yes” means that they require the PV installation to meet the “applicable requirements” of that type. Where a specific standard is mentioned, it is listed in Table 1. Some of the states have made modifications to the standards and are indicated in Table 1.

2.1 National Electric Code (NEC)

The NEC proscribes how to safely wire buildings or stationary locations that are not part of the electric utility. Among other things, the NEC prevents too small of a diameter wires from being used that could get hot and start fires. It also insures that high voltage wires do not accidentally come in contact with each other or other low voltage wires. Of the 24 states that we found to have some type of interconnection standard, 18 or 75% of them specifically require that a PV installation meet NEC requirements (see Table 1). Article 690 of the NEC is specific to PV systems, though other parts of the NEC are relevant too.

2.2 UL1741

The product safety standard UL1741, *Inverters, Converters, and Controllers for Use in Independent Power Systems*, is the safety standard for inverters being used in the USA. UL1741 covers many aspects of the inverter design ranging from how the enclosure is designed, to spacing between traces on the printed circuit board and how the inverter reacts to incorrect utility voltages and frequencies.

When talking about interconnection requirements, the parts of UL1741 that are of most concern are:

- Amount of DC the inverter can inject (45.5)
- The Total Harmonic Distortion (THD) of the output current (45.4.2)
- Inverter’s reaction to abnormal utility voltages (46.2.1)
- Inverter’s reaction to abnormal utility frequencies (46.2.1)
- Reset time of inverter to abnormal conditions (46.2.3)
- Inverter’s reaction to an island condition (46.3.1)

An island occurs when a section of the utility’s distribution network that contains both power sources and loads is disconnected from the rest of the utility’s grid. Under certain combinations of sources and loads, the island has the potential of remaining energized by the sources.

Islands are undesirable for several reasons. If a section of distribution line remains energized after being disconnected from the rest of the grid, it could get out-of-phase with the grid when the automatic reclosers reconnect the island to the grid resulting in damage to the inverters and utility's equipment. Additionally, utility workers are concerned about working on distribution lines that they think are dead when in reality, they may still be energized.

Of the 24 states that we found to have some type of interconnection standard, 18 of them require inverters to meet the UL1741, while three of them require inverters to meet UL1741 with some modifications (see Table 1.). The states that have modifications to UL1741 are California, Ohio, Texas, and Vermont.

California and Texas require different under/over voltage and frequency settings than UL1741. California's requirement, though different than UL1741, is less stringent than UL1741 and is, therefore, superfluous. The Texas PUC in conjunction with utilities determined that a different set of under/over voltage settings are required in Texas. They plan on revisiting these requirements once IEEE 1547 is approved. Ohio requires different under/over voltage and frequency settings too, but only for non-PV systems. PV systems in Ohio just need to meet UL1741 requirements.

California, and Vermont require a higher power factor than UL1741. Fortunately, most inverters easily meet this additional requirement. However it adds an additional cost burden to manufacturers due to additional testing requirements.

In cases where the inverter shuts down due to a detected problem, such as an island, Vermont does NOT require the inverter to wait a certain amount of time before it can go back on line unlike UL1741 which requires a five minute wait.

2.3 IEEE 929

Unlike the proposed standard IEEE P1547, IEEE 929 is only a recommended practice, not a standard. IEEE 929 is the *Recommended Practice for Utility Interface of Photovoltaic (PV) Systems*. However, most of the interconnection recommendations in IEEE 929 are also included in UL1741. In addition IEEE 929 references other standards for allowable THD as well as voltage flicker.

Of the 24 states that we found to have some type of interconnection standard, ten of them require the PV system to meet the relevant IEEE standards, and eight of them specifically mention IEEE 929 (see Table 1.). Four of the states have modified the recommendations in IEEE 929, and they are the same modifications as for UL1741.

2.4 IEEE 519

IEEE 519, *Recommended Practices and Requirements for Harmonic Control in Electric Power Systems*, provides recommended practices for both the customer and the utility in regard to controlling harmonics and voltage flicker on the utility. Too much harmonic power flowing through the utility can damage both the utility's and other customer's equipment. As such, it is desired to keep the harmonic power as low as possible. Inverters, by their very nature, are large producers of harmonic power. Without proper design, this can be a major problem for the utility and other customers.

Voltage flicker refers to fluctuations in the voltage. The term originated from the amount of fluctuations that were noticeable to the human eye through a light bulb. Though four states (see Table 1.), California, Delaware, New York, and Ohio, specifically require that distributed generation meet the voltage flicker requirements of IEEE 519, this is generally not a problem with PV inverters because of their soft-start characteristics.

3 POWER LIMITS

Most of the states have power limits on the maximum size of a PV system before more complex interconnection requirements need to be met. Utilities are concerned about large sources of generation that are installed on their distribution systems. These distribution systems were originally designed for unidirectional power flow. Once generation sources are added to the distribution system, power flow now becomes bi-directional. This can potentially create a less reliable system that operates outside of its design limits.

However, there is near universal agreement that small sources of generation, added to the distribution lines, will not cause any problems. The big debate is on where to draw the dividing line between these two situations.

Many of the states have set maximum limits on the size of a PV system before the utility can start requiring interconnection studies. As shown in Table 2, the limits can vary from 10kW to 100kW. Some states allow commercial buildings to have a higher limit. Often commercial buildings are connected to higher capacity distribution lines than residential buildings and can therefore be allowed a larger PV system. Also commercial building's power demand more closely matches the PV system output than the residential usage.

TABLE 2: PV SYSTEM POWER LIMITS

State	Residential Limit	Commercial Limit
AR	25kW	100kW
CA	20kVA	20kVA
CO	25kW	25kW
DE	25kW	25kW
FL	None	None
GA	10kW	100kW
HI	10kW	10kW
IL	None	None
MD	80kW	80kW
MO	None	None
MT	None	None
NV	10kW	10kW
NH	10kW	10kW
NJ	100kW	100kW
NM	10kW	10kW
NY	10kW	10kW
OH	None	None
OR	25kW	25kW
TX	50kW?	50kW?
UT	25kW	25kW
VT	15kW	15kW
VA	10kW	25kW
WA	25kW	25kW
WY	25kW	25kW

4 UTILITY SIDE CONSIDERATIONS

On the utility side of a PV system, there are several requirements that some of the states have added. They are a disconnect switch, a dedicated transformer, and cap on the maximum number of PV systems using net metering (see Table 3).

Table 3, addresses state requirements. In cases where the state does not require the item, individual utilities often can. Identifying the requirements of each utility is beyond the scope of this paper.

4.1 Disconnect Switch

Utilities often require that an outside, visible, and accessible disconnect switch be available for them to use. They feel that they need this in case the PV system interferes with the grid, or if the grid is down, the lineman may want to disconnect all known sources of generation before working on the lines.

TABLE 3: UTILITY SIDE REQUIREMENTS

State	Disconnect Switch	Dedicated Transformer	Capacity Constraints
AR	No	No	No
CA	Sometimes	No	Yes
CO	Yes	No	Yes
DE	Sometimes	No	Yes
FL	Sometimes	No	No
GA	No	No	Yes
HI	No	No	Yes
IL	Yes	No	No
MD	No	No	Yes
MO	Yes	No	No
MT	No	No	No
NV	No	No	No
NH	Sometimes	No	Yes
NJ	No	No	Yes
NM	Yes	Sometimes	No
NY	Yes	Sometimes	No
OH	Sometimes	No	No
OR	No	No	Yes
TX	Yes	No	No
UT	No	No	No
VT	Yes	No	Yes
VA	Sometimes	No	Yes
WA	No	No	Yes
WY	Yes	No	No

The use of a disconnect switch has been controversial since some utilities do not require one at all, while others maintain that they absolutely need one. This dichotomy can be seen by looking at the states' requirements. About half of the states with interconnection requirements also require a disconnect switch. The other half do not mention disconnect switches in their regulations at all.

4.2 Dedicated Transformer

Dedicated transformers, like fences, can make adjacent electrical customers good neighbors by isolating electrical noise created by one customer from affecting another customer. However, Federal Communication Commission (FCC) and UL requirements assure that inverters do not inject appreciable amounts of noise into the grid. Consequently only two states require dedicated transformers for PV system customers, and only then for special situations.

New York allows utilities to require a dedicated transformer for small PV system. However, the utility is then only allowed to recover up to $350 of the cost of the transformer. Since a dedicated utility transformer can cost about ten times this amount, very few dedicated transformers will be required in New York State!

4.3 Capacity Constraints

Some states have imposed a cap on the maximum number of PV systems using net metering. These requirements range from 0.05% of the utility's annual peak energy demand in New Hampshire to 1% of the monthly peak demand in Colorado. However, Vermont determines the cap by the capacity of the distribution line serving the PV system customer, not on the overall capacity of the utility.

5 SURGE WITHSTAND REQUIREMENTS

Since the majority of the distribution lines are overhead wires that are exposed to the elements, they can occasionally receive power surges from nearby lightning. Additionally, surges can originate from other sources such as switching capacitor banks for voltage or power factor regulation, periodic transients from thyristor power converters, and load switching.

By hardening the inverter so that only the worst surges can damage it, the customer will have a much more reliable product as well as protecting the utility grid from an inverter malfunction. IEEE has developed a national recommended practice that describes various types of surges that are commonly seen on the utility grid and suggests surge immunity tests that can be performed on any type of equipment connected to a low-voltage distribution grid. The severity of the tests depends on the location where the equipment will be installed. Several states mandate that selected tests described in ANSI/IEEE C62.41, *Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits*, be performed on grid-tied inverters.

Presently only three states have surge requirements, California, New Hampshire, and New York (see Table 4). Unfortunately, New Hampshire's surge level requirements are not consistent with California's and New York's surge level requirements.

6 INTERCONNECTION STUDIES

Many utilities want to perform an interconnection study that examines line capacity, relay compatibilities, grounding schemes, and other aspects of the local utility grid. For medium to large size generation sources, this can be a reasonable and prudent action to take. However for small PV systems, this is generally an unnecessary barrier.

TABLE 4: ADDITIONAL STATE IMPOSED REQUIREMENTS

State	Surge Require-ments	Inter-connection Studies	Additional Requirements
AR	No	No	Yes
CA	Yes	Required	None
CO	No	No	None
DE	No	Not allowed	Yes
FL	No	No	Yes
GA	No	No	None
HI	No	No	Yes
IL	No	No	Yes
MD	No	No	Yes
MO	No	No	None
MT	No	No	None
NV	No	No	None
NH	Yes	Allowed	None
NJ	No	Not allowed	Yes
NM	No	No	Yes
NY	Yes	No	Yes
OH	No	No	Yes
OR	No	No	None
TX	No	No	Yes
UT	No	No	None
VT	No	Sometimes	Yes
VA	No	No	None
WA	No	No	None
WY	No	No	None

Only five states address interconnection studies (see Table 4.). California requires a study for generation sources that will export to the grid, i.e. PV systems. New Hampshire and Vermont allow studies in specific cases. New Jersey and Delaware specifically prohibit interconnection studies (or at least charging the customer for an interconnection study). The rest of the states do not address this issue.

7 ADDITIONAL REQUIREMENTS

Many of the states have imposed requirements in addition to those discussed so far.

7.1 Additional Utility Requirements

The most popular additional state requirement is allowing the utilities to impose additional requirements. Six of the states mention in their requirements that the utility can add additional requirements. Of these six states, four of them will only allow the utilities to imposed additional requirements that are approved by the states public utility commission or similar body.

7.2 Periodic Disconnect Test

Several states do require that the customer open the disconnect switch and check that the inverter shuts down on a periodic basis. The period ranges from one year for New Jersey and New York to four years for California.

7.3 Commissioning Tests Required

Three states, California, Texas, and Vermont, require commissioning tests to be performed when generation sources are installed. For a small PV system, the commissioning test consists of the disconnect test mentioned above.

7.4 Power Loss and Protection Limits

New York State requires that the loss of external or internal backup battery power should not compromise the protection limit settings.

7.5 Maintenance Activity Records

Texas requires that a record of all maintenance on a generation source be recorded. This makes sense for the utility's point-of-view and will also help push inverter manufacturers to produce inverters that require as little maintenance as possible.

8 CONCLUSION

This paper has reviewed the regulations of the 24 states that have interconnection requirements for PV systems. Almost all of these require adherence to the national standards and recommended practices of UL1741 and IEEE929. Unfortunately, many have modified these and/or imposed additional standards, adding to the complexity and cost of product development and production.

Some of these additional or modified requirements make sense and will make for better inverters and PV installations. Some do not apply to PV systems or can easily be met by PV systems, while a few are barriers to entry for customers that want PV systems.

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10 REFERENCES

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