

Smart Inverter WG

Technical Requirement Recommendations Highlights

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Purpose for the WG

- ▶ The Smart Inverter Working Group (SIWG) was jointly sponsored by the CPUC Energy Division and the CEC in 2012 to explore the smart inverter functionalities for facilitating large penetrations of distributed generation and storage into California's grid while maintaining high levels of system reliability and power quality, and
- ▶ To make recommendations to the CPUC on which new smart inverter capabilities should be included in Rule 21.

Underlying Drivers

- ▶ Germany's effort to retrofit over 315,000 inverters at hundreds of millions of dollars to avoid potential system reliability impact at high DG penetrations
- ▶ Existing requirements specified in IEEE-1547 and CA Rule 21 are based on simplified low penetration methodology, similar to Germany, which may cause reliability issues at high penetration scenarios.
- ▶ CEC's leadership role in addressing potential adverse system impacts at high DG penetration.
- ▶ Desire to use potential inverter capabilities, to mitigate the potentially higher impacts and to improve distribution level service reliability, i.e. microgrids, and power quality.

Smart Inverters WG Chronology

- ▶ September 26, 2012: Phase II of Interconnection Proceeding – Issue 6:
 - *“Technical Operating Standards. This issue includes potential modifications to technical operating standards, limited to smart inverter functionalities and generation output metering, where such modifications are responsive to the goals of this proceeding and other potential reliability needs.”*
- ▶ Energy Division Staff announced the formation of the Smart Inverter Working Group in an email to the service list in Rulemaking 11-09-11 on February 13, 2013.
- ▶ Workshop held on June 21, 2013

SIWG Chronology–continued

- ▶ Smart Inverter Working Group recommendations submitted to Energy Division in December of 2013/January 2014

“Recommendations for Updating the Technical Requirements for Inverters in Distributed Energy Resources”

- Includes detailed Phase I Autonomous Inverter Functionalities recommendations
 - Includes Phase II and III information with full understanding that future phases require further collaboration and work.
- ▶ Wed. February 12, 2014 – Commissioner Picker becomes new assigned Commissioner on Interconnection Proceeding
 - ▶ Thursday, February 19, 2014: Prehearing Conference held on SIWG Recommendations
 - Regarding the evidentiary weight of the SIWG recommendations, primarily on Phase 1 recommendations.
 - Procedural in nature.
 - Manufacturers expressed concerns about Phase 2 and 3 and the associated cost and time line.
 - ▶ Awaiting decision from the Judge.

Challenges associated with distributed generation

- ▶ The existing distribution system was designed to serve load and regulate voltage radially, from a single source, in a tree fashion with progressively smaller conductors, at lower cost.
- ▶ Distribution system is regulated to $\pm 5\%$ of nominal voltage in the radial direction to provide proper voltage automatically from zero load to full load to distribution customer equipment.
- ▶ It was not designed for bi-directional flow associated with generation.
- ▶ It also was not designed for frequent large power fluctuations that may occur with intermittent sources such as PV.

Existing requirements

- ▶ The existing Rule 21 recognized that if the DG is operating within the existing distribution system design parameters, it has minimal system impact.
- ▶ It identified the low impact conditions and provided simplified requirements to allow small DG units at low penetration levels to be interconnected quickly so long as safety issues are addressed.
- ▶ Typically, there are sufficient existing design & operating margin to accommodate the small DG units when they do trip off-line. So, some overtrip of the DG was deemed tolerable at the local level.
- ▶ This significantly simplified the review/approval process and reduced the interconnect review time for the small units.

Current status

- ▶ The vast majority of the existing inverters are designed for grid interactive mode, set at unity power factor, and certified not to operate when the grid is de-energized, i. e., certified anti-islanding. These inverters produce the maximum as-available energy and rely on the grid for voltage and frequency support.
- ▶ Some inverters are designed for stand-alone operation and have the capability to follow load and regulate voltage after they are isolated from the grid. But these schemes are much more complicated/customized and require more review.

Existing Rule 21 Voltage Settings

Table D.1: Voltage Trip Settings

Voltage at Point of Common Coupling % of Nominal Voltage	Maximum Trip Time ⁽¹⁾	
	# of Cycles	Seconds
Less than 50%	10 Cycles	0.16 Seconds
$50\% \leq V < 88\%$	120 Cycles	2 Seconds
$88\% \leq V \leq 110\%$	No Trip	
$110\% < V \leq 120\%$	60 Cycles	1 Second
Greater than 120%	10 Cycles	0.16 Seconds

Existing Rule 21 Frequency Settings

Table D.2: Frequency Trip Settings

Generating Facility Rating	Frequency Range	Maximum Trip Time ⁽¹⁾
Less or equal to 30 kW	Less than 59.3 Hz	10 Cycles
	Greater than 60.5 Hz	10 Cycles
Greater than 30 kW	Less than 57 Hz	10 Cycles
	$59.8 \text{ Hz} > f > 57 \text{ Hz}$	10 – 18,000 Cycles ^{2,3}
	Greater than 60.5 Hz	10 Cycles

Preparing for the future

- ▶ As California heads toward high renewable penetrations, the simple distribution interconnection requirements set up for low penetration, contained in IEEE-1547, UL-1741, and Rule 21, need to be revised.
- ▶ At higher penetration, the cumulative DG impacts are no longer negligible and their aggregated impact to the grid during major disturbances has to be considered.
- ▶ Conversely, at higher DG penetrations, there also may be more opportunities to capture the potential benefits of DG.

Smart Inverter WG Recommendations (Focused on Phase 1)

Note: Phase 2 & 3 details will be ironed out after Phase 1 implementation is underway

Phase 1 Autonomous DER Functions

It is recommended that the following autonomous DER functions should be mandatory in Rule 21 for smart inverter systems as Phase 1:

- ▶ **Support anti-islanding to trip off under extended anomalous conditions**
- ▶ **Provide ride-through of low/high voltage excursions beyond current limits**
- ▶ **Provide ride-through of low/high frequency excursions beyond current limits**
- ▶ **Provide volt/var control through prescribed reactive power injection/absorption autonomously**
- ▶ **Define default and emergency ramp rates as well as high and low limits**
- ▶ **Provide/absorb reactive power by a fixed power factor**
- ▶ **Reconnect by “soft-start” methods**

Default Activation States for Phase 1 Functions

Using the default values described in each of the functions, the default activation states for the Phase 1 functions are:

- ▶ Anti-islanding – activated
- ▶ L/HVRT – activated
- ▶ L/HFRT – activated
- ▶ Dynamic Volt/Var operations – deactivated
- ▶ Ramp rates – activated
- ▶ Fixed power factor – activated
- ▶ Reconnect by “soft-start” methods – activated

Default Prioritization of Phase 1 Functions

The following is a proposed prioritization for inverters to decide which function supersedes the other functions, for any conflicts that may arise.

- ▶ Prioritized functionality:
- ▶ 1. Voltage and Frequency Ride Through
- ▶ 2. Frequency/Watt
- ▶ 3. Commanded (set P, limit P)
- ▶ 4. Set PF or Volt/Var, Volt/W

Proposed default Rule 21 voltage ride-through values

Voltage Level Multiplier of Nominal Voltage	Stay Connected Until		Voltage Level Multiplier of Nominal Voltage	Disconnect by
			>1.2	< 0.16 sec.
1.09–1.17	12 sec.		1.1 – 1.2	13 sec.
0.92–1.09	Indefinite		0.88 – 1.1	Do not disconnect
0.7 – 0.92	20 sec.		0.6 – 0.88	21 sec.
0.5 – 0.7	10 sec.		0.45 – 0.6	11 sec.
0 – 0.5	1.0 sec. (range between 0.16 to 2.0 sec.)		0 – 0.45	2.5 sec.

Proposed default interconnection system response to abnormal frequencies

System frequency	Frequency settings (Hz)	Range of adjustability (Hz)	Default clearing time (s)	Range of adjustability (s)
$62 \leq f$	62.0	62-64	0.16	0-300
$60.0 < f < 62$	60.5	60 – 62	300	0 – 300
$60.2 < f \leq 61.5$	I-DER power reduction permitted			
$58.5 < f < 60.5$			Indefinite	
$57.0 < f \leq 59.5$	58.5	53 – 60	300	0 – 600
$f \leq 57.0$	57	53 – 57	0.16	0 – 5

Implementation challenges– Phase 1

- ▶ The coordination between multiple units, utilizing active volt/var control, and the existing voltage regulation equipment need to be tested and verified to avoid potential voltage problems to existing distribution customers.
- ▶ Identify conditions where active volt/var feature will be useful and should be turned on.
- ▶ The existing anti-islanding schemes need to be tested at the new expanded V/F ride through settings.

Questions?

- ▶ More information about the SIWG and the specific Phase 2 & 3 recommendations along with the associated reference documents can be found on:
- ▶ http://www.energy.ca.gov/electricity_analysis/rule21/index.html