

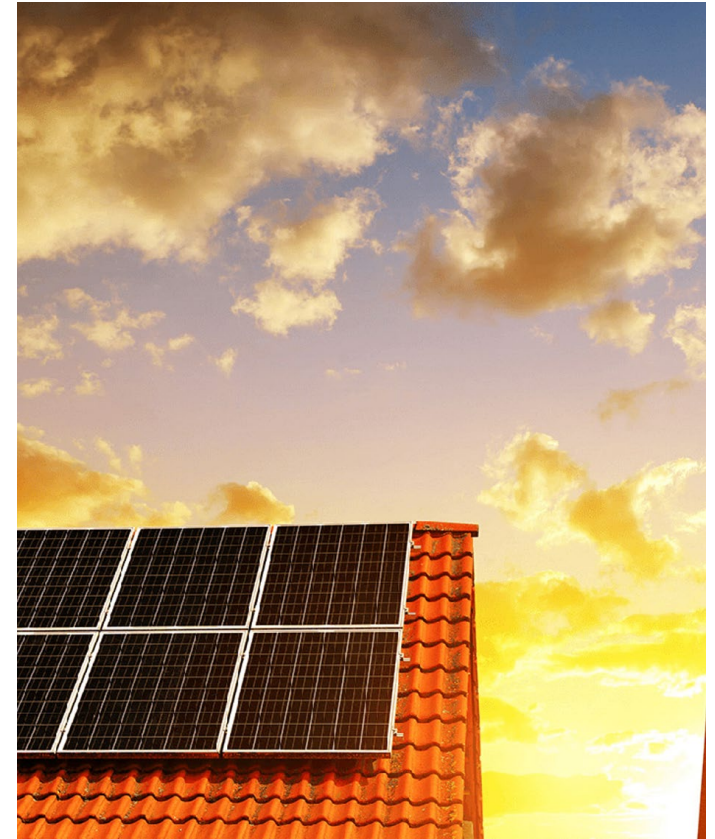
Interconnection Requirements Manual Updates

Distributed Resources Engineering
Joel Hornburg, Marlissa Lucero, and Danny Miranda



Topics of Discussion

- Distributed Resources Engineering
- Interconnection Requirements Manual (IRM)
 - A Collaborative Update Process (Joel)
- IRM changes (Marlissa)
 - Disconnects (labeling, use cases, new keynotes)
 - Sample diagrams
 - Elevation and site plans
 - Tour of APS.COM
- Smart inverter changes (Danny)
- General reminders
 - Approved equipment reminders - cannot modify equipment in the field



DRE's Mission:

To partner with our customers to sustainably integrate DERs to the distribution grid with a focus on safety, reliability, and customer affordability.



Interconnection Requirements Manual (IRM) A Collaborative Update Process

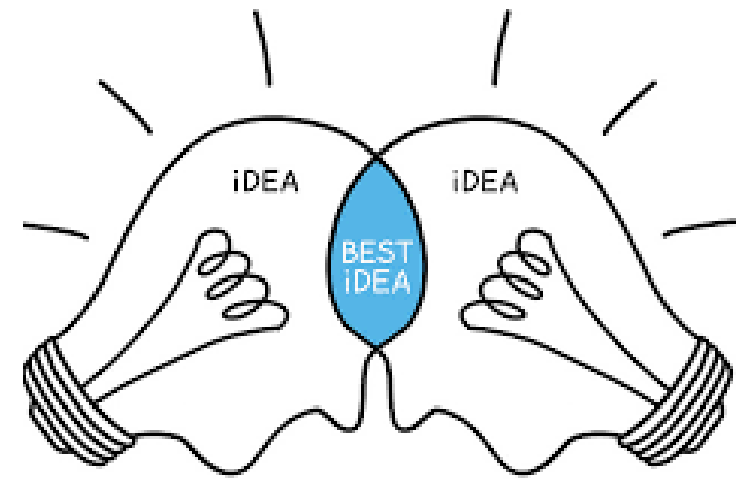
- Focus on safe, reliable, and efficient interconnection of DERs interconnecting to the distribution system
- Updating the IRM is an ongoing collaborative process involving manufacturers, stakeholders, and industry experts.
- APS monitors technological advances, national codes and standards, as well as industry best practices in order to keep the IRM representative of current best practices



Interconnection Requirements Manual (IRM)

A Collaborative Update Process

- APS regularly engages with stakeholders to address questions, concerns, and recommendations for updates.
- APS evaluates and investigates suggestions, incorporating them when feasible.
- APS holds collaborative working sessions with stakeholders at least twice a year, or more frequently if necessary, to discuss changes to the IRM.
- Certain updates that Marlissa will share come from these collaborative discussions.



Key IRM Updates

Marlissa Lucero



Key Changes

- Section 8
 - Minimizing the number of disconnects (8.6)
 - Clarification of equipment locations and access (8.2)

Please read through the revised IRM for further information and updates.

Minimizing the Number of Disconnects (8.6)



Minimizing the Number of Disconnects

Approved Fused Disconnects may be used for all applications

APS Equipment Review Process

All submittals must be received no later than the first Wednesday of each month. Following review, approved equipment will be added to PowerClerk within 14 days. See below for how to submit different types of equipment.

For disconnect switches, meter sockets, MSAs, SESSs, and similar devices

Equipment must be physically reviewed by APS. To submit, mail the equipment to:

Attn: Meter Shop
Arizona Public Service
2121 W Cheryl Dr
Phoenix, AZ 85021

When the equipment is shipped, email renewables@aps.com with the subject line "Equipment Submittal" containing the following information: model, tracking number, and your contact information.



Labeling

- Unfused Utility Disconnect: **UTILITY DISCONNECT**
- Fused Utility Disconnect (Load Side/Load Side Tap): **FUSED UTILITY DISCONNECT**
- Fused Utility Disconnect (Supply Side Taps) or MSAs: **SERVICE/UTILITY DISCONNECT**

All Disconnects must be approved models.

aps.com/dg





Your Journey to Adding Rooftop Solar



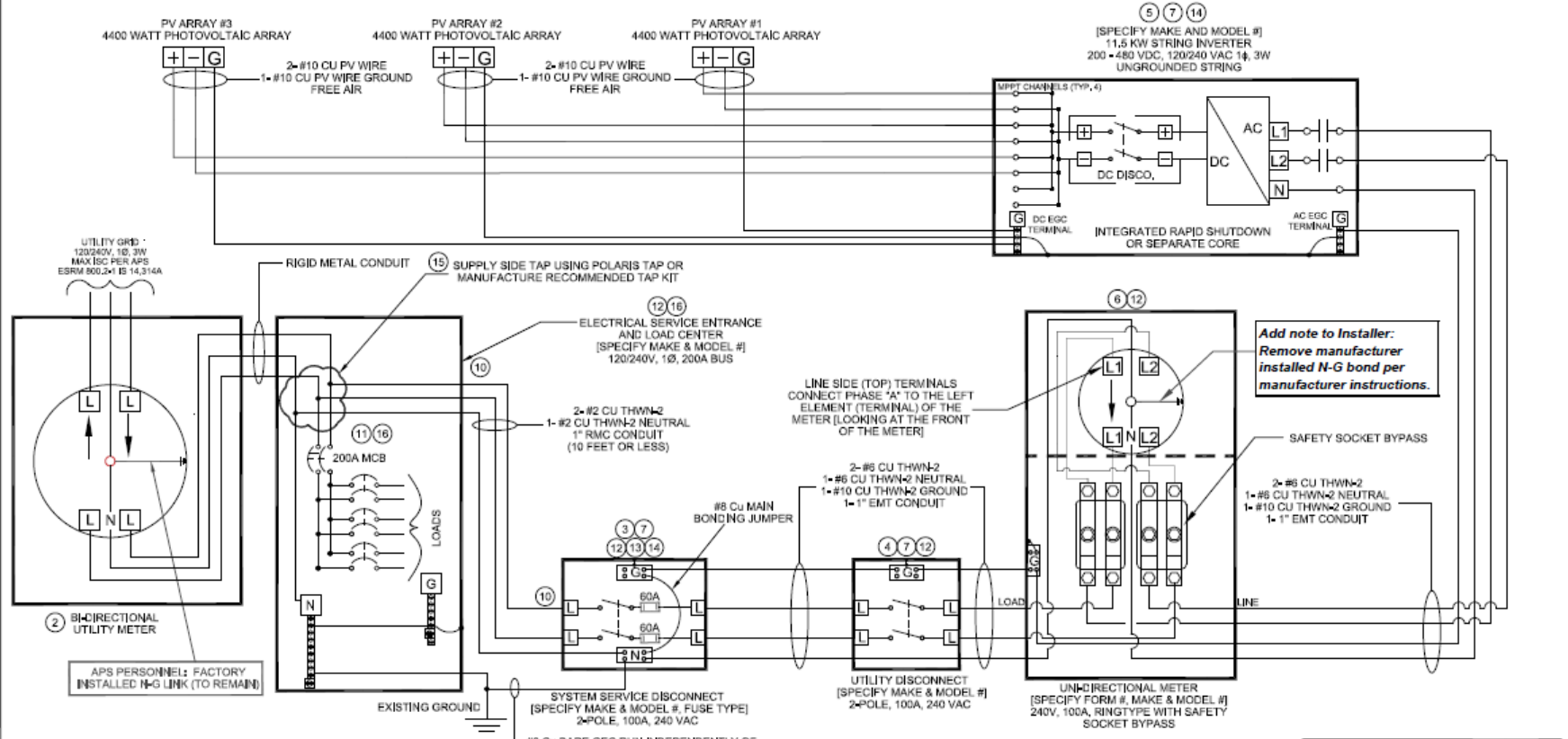
Installing clean energy technologies like rooftop solar and batteries at your home or business are good for the environment and can reduce your energy bill. It's also a big decision. There are many factors to consider before you make a choice and sign a contract. Learn more about your options, questions to ask and the connection process.

Follow the steps below to make an informed decision on your home energy.

Exploring Rooftop Solar for Your Home
Arizona Public Service
Use SolarSmart online tool
Watch on YouTube

NOTE: All equipment must be utilized in accordance with the manufacturer's intended use and design specifications.

REV.	DESCRIPTION:	DATE
C	FUSED DISCONNECT	1-26-17
D	2023 NEC SET INCORPORATING REVISED APS REQUIREMENTS	02-13-26



- NOTES:**
- EQUIPMENT SHALL BE INSTALLED AND LABELED IN ACCORDANCE WITH THE NEC AND ALL APPLICABLE REQUIREMENTS OF THE SERVING ELECTRIC UTILITY COMPANY AND OF THE LOCAL AUTHORITY HAVING JURISDICTION.
 - BIDIRECTIONAL UTILITY METER INSTALLED BY UTILITY COMPANY.
 - LABEL "SYSTEM SERVICE DISCONNECT." KEEP COVER LOCKED; SWITCH MUST SHOW VISIBLE OPEN. INSTALL PER UTILITY REQUIREMENTS AND NEC 705.20.
 - LABEL "UTILITY DISCONNECT." KEEP COVER LOCKED; SWITCH MUST SHOW VISIBLE OPEN. INSTALL PER UTILITY REQUIREMENTS AND NEC 705.20. ACCEPTABLE OPTIONS: (1) SWITCH WITH VIEWING WINDOW AND CUSTOMER-INSTALLED LOCK, OR (2) A SHARED LOCK PER UTILITY REQUIREMENTS.
 - LABEL "PV SYSTEM DISCONNECT" PER NEC 690.13(B). ENCLOSURE DOOR TO BE LOCKED/SECURED PER NEC 690.13(A)(2). SHOW SWITCH INTERNAL WIRING CONFIGURATION PER MANUFACTURER'S REQUIREMENTS. DISCONNECT SHALL BE ACCESSIBLE AND LABELED IN ACCORDANCE WITH NEC 690.12. RAPID SHUTDOWN OF PV SYSTEMS ON BUILDINGS.
 - LABEL "UNIDIRECTIONAL METER." METER ENCLOSURE AND SOCKET PROVIDED AND INSTALLED BY CUSTOMER PER APS ESRM. METER PROVIDED BY APS. METERING EQUIPMENT SHALL BE INSTALLED PER NEC 110.2(B) AND MANUFACTURER'S INSTRUCTIONS. PROVIDE WARNING "LINE AND LOAD TERMINALS MAY BE ENERGIZED IN THE OPEN POSITION."
 - PROVIDE WARNING SIGN PER NEC 690.13(B) READING "WARNING-ELECTRIC SHOCK HAZARD-DO NOT TOUCH TERMINALS-TERMINALS ON BOTH LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION."
 - NOT USED
 - METALLIC CONDUIT SHALL BE USED WITHIN BUILDING PER NEC 690.31(D)(1).
 - GROUNDING BUSHINGS INSTALLED AT EVERY ENTRY AND EXIT POINT TO ENCLOSURES WITH RIGID METALLIC CONDUIT (RMC).
 - A PLACARD OR DIRECTORY IS INSTALLED AT THE SERVICE ENTRANCE WITH EXPLICIT DIRECTIONS TO THE LOCATION OF THE UTILITY DISCONNECT SWITCH AS REQUIRED BY APS AND NEC 705.10.
 - EQUIPMENT SHALL BE LISTED, TESTED AND MARKED TO WITHSTAND THE AVAILABLE SHORT CIRCUIT CURRENT.
 - INSTALL AS REQUIRED TO ENSURE UTILITY DISCONNECT SWITCH AND UNIDIRECTIONAL METER AFC RATINGS ARE NOT EXCEEDED.
 - SUPPLY SIDE CONNECTION IS INSTALLED PER NEC 250, NEC 705, APS ESRM AND APS INTERCONNECTION REQUIREMENTS. LABEL "SERVICE DISCONNECT SWITCH." SWITCH COVER TO BE LOCKED AT ALL TIMES.
 - SUPPLY SIDE CONNECTION IS INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS. DOCUMENTATION IS INCLUDED WITH THE APS INTERCONNECTION APPLICATION. UNSURE UL LISTED CONNECTORS.
 - LABEL "WARNING-A GENERATION SOURCE IS CONNECTED TO THE SUPPLY (UTILITY) SIDE OF THE SERVICE DISCONNECTING MEANS. FOLLOW PROPER LOCKOUT/TAGOUT PROCEDURES TO ENSURE THE PHOTOVOLTAIC SYSTEM UTILITY DISCONNECT SWITCH IS OPENED PRIOR TO PERFORMING WORK ON THIS DEVICE."

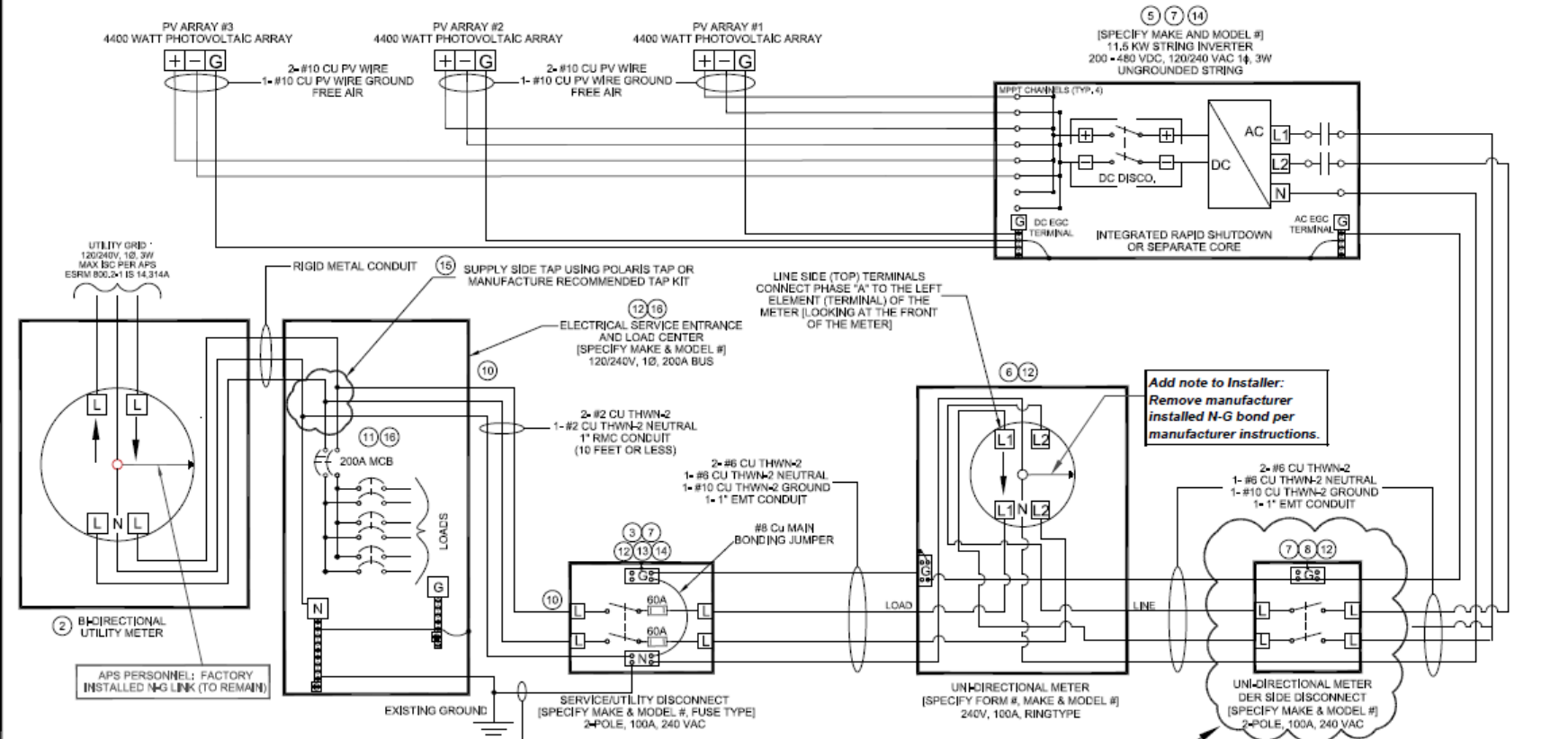
NOTE: SYSTEM DESIGNED IN ACCORDANCE WITH THE 2023 N.E.C.

This Sample Drawing Is for illustration purposes only and is not to be used for design or construction. This drawing and its submittal for end use is not implied. The intent is to only illustrate typical minimum information required at time of application to APS. Additional information may be required.

1234 South Main Street Any City, Arizona 85123 Tel: 602-655-6555		ABC SOLAR COMPANY, INC.	
THREE-LINE ELECTRICAL DIAGRAM 11.5 KW AC PHOTOVOLTAIC SYSTEM 333 E. CACTUS BIRD RD. ANY CITY, AZ 85123			
APPROVALS	DATE	SIZE	DRAWING NO.
DRAWN ABC	6-28-05	B	0000-0002
CHECKED		SCALE	REV. D
ENGINEER		NA	
REV. D	02-13-26		
ABC PROJECT #1111-8999			SHEET 2 of 3

NOTE: All equipment must be utilized in accordance with the manufacturer's intended use and design specifications.

REV.	DESCRIPTION:	DATE
C	FUSED DISCONNECT	1-26-17
D	2023 NEC SET INCORPORATING REVISED APS REQUIREMENTS	02-13-26



- NOTES:**
- EQUIPMENT SHALL BE INSTALLED AND LABELED IN ACCORDANCE WITH THE NEC AND ALL APPLICABLE REQUIREMENTS OF THE SERVING ELECTRIC UTILITY COMPANY AND OF THE LOCAL AUTHORITY HAVING JURISDICTION.
 - BIDIRECTIONAL UTILITY METER INSTALLED BY UTILITY COMPANY.
 - LABEL "SERVICE/UTILITY DISCONNECT," KEEP COVER LOCKED; SWITCH MUST SHOW VISIBLE OPEN, INSTALL PER UTILITY REQUIREMENTS AND NEC 705.20, ACCEPTABLE OPTIONS; (1) SWITCH WITH VISIBLE WINDOW AND CUSTOMER-INSTALLED LOCK, OR (2) A SHARED LOCK PER UTILITY REQUIREMENTS.
 - NOT USED
 - LABEL "PV SYSTEM DISCONNECT" PER NEC 690.13(B), ENCLOSURE DOOR TO BE LOCKED/SECURED PER NEC 690.13(A)(7), (SHOW SWITCH INTERNAL WIRING CONFIGURATION PER MANUFACTURER'S REQUIREMENTS), DISCONNECT SHALL BE ACCESSIBLE AND LABELED IN ACCORDANCE WITH NEC 690.12, RAPID SHUTDOWN OF PV SYSTEMS ON BUILDINGS.
 - LABEL "UNIDIRECTIONAL METER," METER ENCLOSURE AND SOCKET PROVIDED AND INSTALLED BY CUSTOMER PER APS ESRM. METER PROVIDED BY CUSTOMER (AS REQUIRED), METERING EQUIPMENT SHALL BE INSTALLED PER NEC 110.3(B) AND MANUFACTURER'S INSTRUCTIONS. PROVIDE WARNING "LINE AND LOAD TERMINALS MAY BE ENERGIZED IN THE OPEN POSITION."
 - PROVIDE WARNING SIGN PER NEC 690.13(B) READING "WARNING-ELECTRIC SHOCK HAZARD-DO NOT TOUCH TERMINALS-TERMINALS ON BOTH LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION."
 - REQUIRED FOR GRID FORMING SYSTEMS, LABEL "UNIDIRECTIONAL METER DER SIDE DISCONNECT SWITCH," SWITCH COVER TO BE LOCKED AT ALL TIMES, AND SHALL BE VISUAL OPEN AND ACCESSIBLE PER UTILITY REQUIREMENTS AND CONFORM TO NEC 705.20.
 - METALLIC CONDUIT SHALL BE USED WITHIN BUILDING PER NEC 690.31(D)(1).
 - GROUNDING BUSHINGS INSTALLED AT EVERY ENTRY AND EXIT POINT TO ENCLOSURES WITH RIGID METALLIC CONDUIT (RMC).
 - A PLACARD OR DIRECTORY IS INSTALLED AT THE SERVICE ENTRANCE WITH EXPLICIT DIRECTIONS TO THE LOCATION OF THE UTILITY DISCONNECT SWITCH AS REQUIRED BY APS AND NEC 705.14.
 - EQUIPMENT SHALL BE LISTED, TESTED AND MARKED TO WITHSTAND THE AVAILABLE SHORT CIRCUIT CURRENT.
 - INSTALL AS REQUIRED TO ENSURE UTILITY DISCONNECT SWITCH AND UNIDIRECTIONAL METER AFC RATINGS ARE NOT EXCEEDED.
 - SUPPLY SIDE CONNECTION IS INSTALLED PER NEC 250, NEC 705, APS ESRM AND APS INTERCONNECTION REQUIREMENTS, LABEL "SERVICE DISCONNECT SWITCH," SWITCH COVER TO BE LOCKED AT ALL TIMES.
 - SUPPLY SIDE CONNECTION IS INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS, DOCUMENTATION IS INCLUDED WITH THE APS INTERCONNECTION APPLICATION, UNSURE UL LISTED CONNECTORS.
 - LABEL "WARNING-A GENERATION SOURCE IS CONNECTED TO THE SUPPLY (UTILITY) SIDE OF THE SERVICE DISCONNECTING MEANS. FOLLOW PROPER LOCKOUT/TAGOUT PROCEDURES TO ENSURE THE PHOTOVOLTAIC SYSTEM UTILITY DISCONNECT SWITCH IS OPENED PRIOR TO PERFORMING WORK ON THIS DEVICE."

NOTE: ONLY NEEDED FOR GRID FORMING SYSTEMS, SEE NOTE #8

NOTE: SYSTEM DESIGNED IN ACCORDANCE WITH THE 2023 N.E.C.

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1234 South Main Street Any City, Arizona 85123 Tel: 602-655-6555		ABC SOLAR COMPANY, INC.	
APPROVALS		DATE	
DRAWN ABC		6-28-05	
CHECKED			
ENGINEER			
REV. D		02-13-26	
ABC PROJECT #111-9999		SIZE B	DRAWING NO. 0000-0002
SCALE NA		REV. D	SHEET 2 of 3

Clarification of Equipment Locations and Access (8.2)



Equipment Locations and Access

- Location of new production equipment may be adjacent to the existing SES even when located in a fenced yard
 - Customers may be contacted to schedule an appointment to access the equipment



Site Plan Notes

Notes to remain:

NOTE: REFERENCE SECTION 301.15 OF THE APS ESRM FOR ELECTRIC METER SEPARATION BETWEEN WATER AND GAS.

NOTE: WORKSPACE IN FRONT OF AC ELECTRICAL SYSTEM COMPONENTS SHALL BE IN ACCORDANCE WITH APS AND NEC REQUIREMENTS. FOR APS REQUIREMENTS, REFERENCE SECTION 300 OF THE APS ESRM AND SECTION 8.2 OF THE APS INTERCONNECTION REQUIREMENTS.

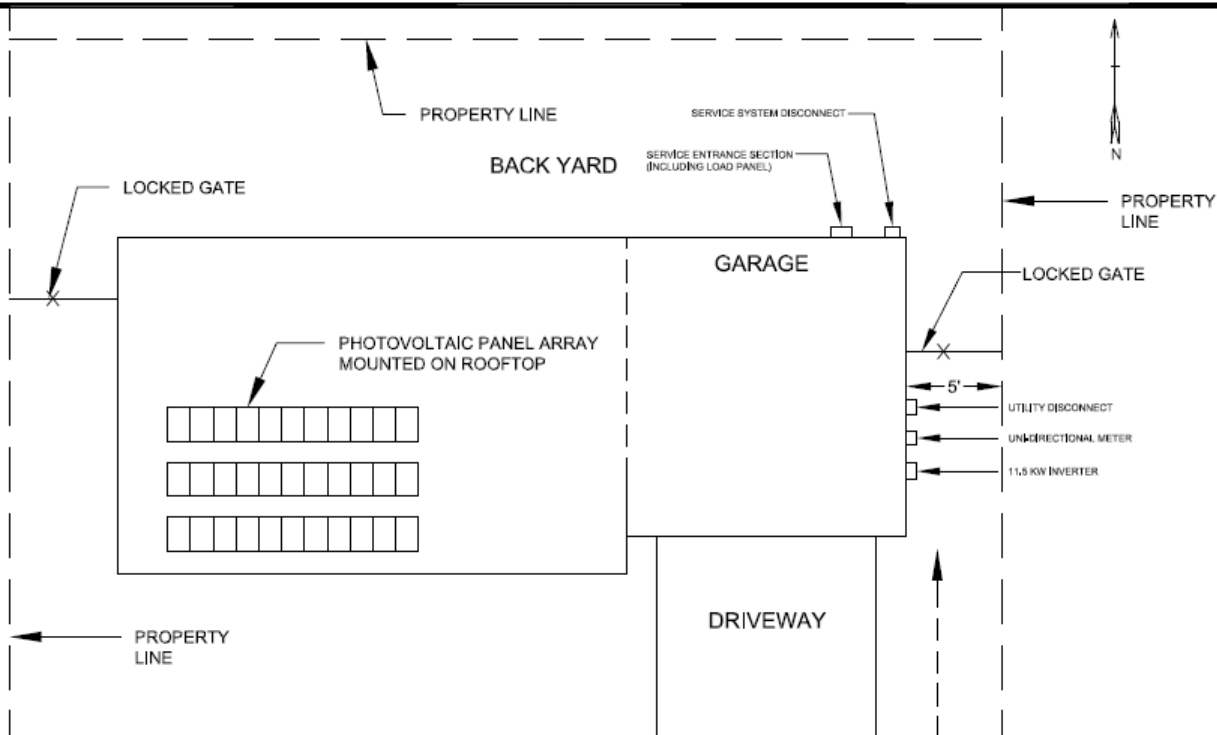
New:

NOTE: UTILITY PERSONNEL REQUIRE COORDINATED ACCESS TO ALL DER SYSTEM COMPONENTS, SERVICE DISCONNECTS, METERING, AND SERVICE EQUIPMENT FOR SCHEDULED MAINTENANCE AND SAFETY INSPECTIONS. CUSTOMERS ARE RESPONSIBLE FOR ENSURING THAT ACCESS IS AVAILABLE AND MAY BE CONTACTED BY THE UTILITY TO ARRANGE SITE VISITS WHEN EQUIPMENT IS LOCATED WITHIN FENCED OR SECURED AREAS. EMERGENCY ACCESS TO THIS EQUIPMENT MUST BE AVAILABLE AT ALL TIMES.

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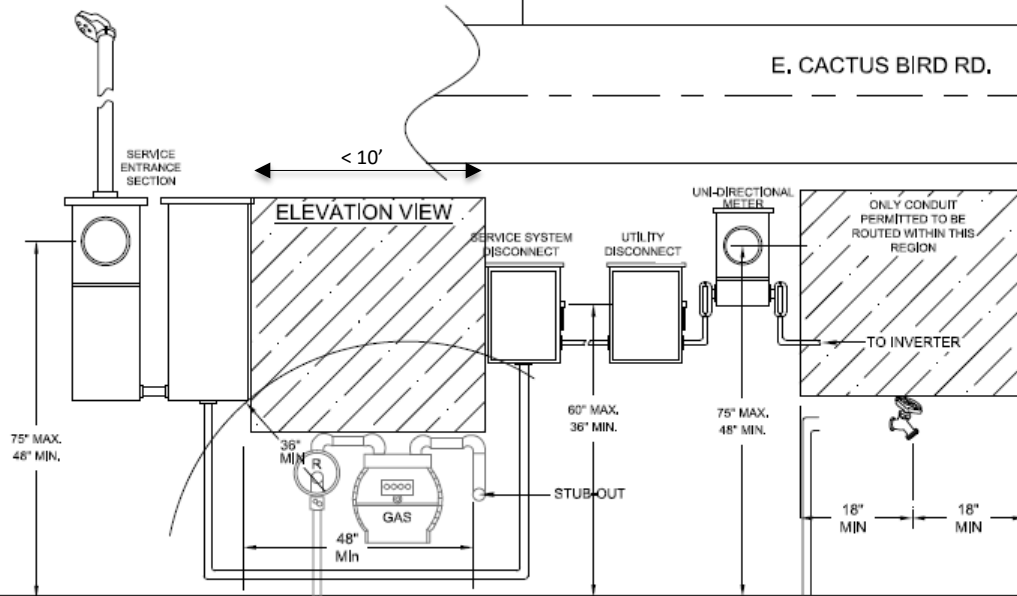
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E. CACTUS BIRD RD.

APS 24-HR ACCESS



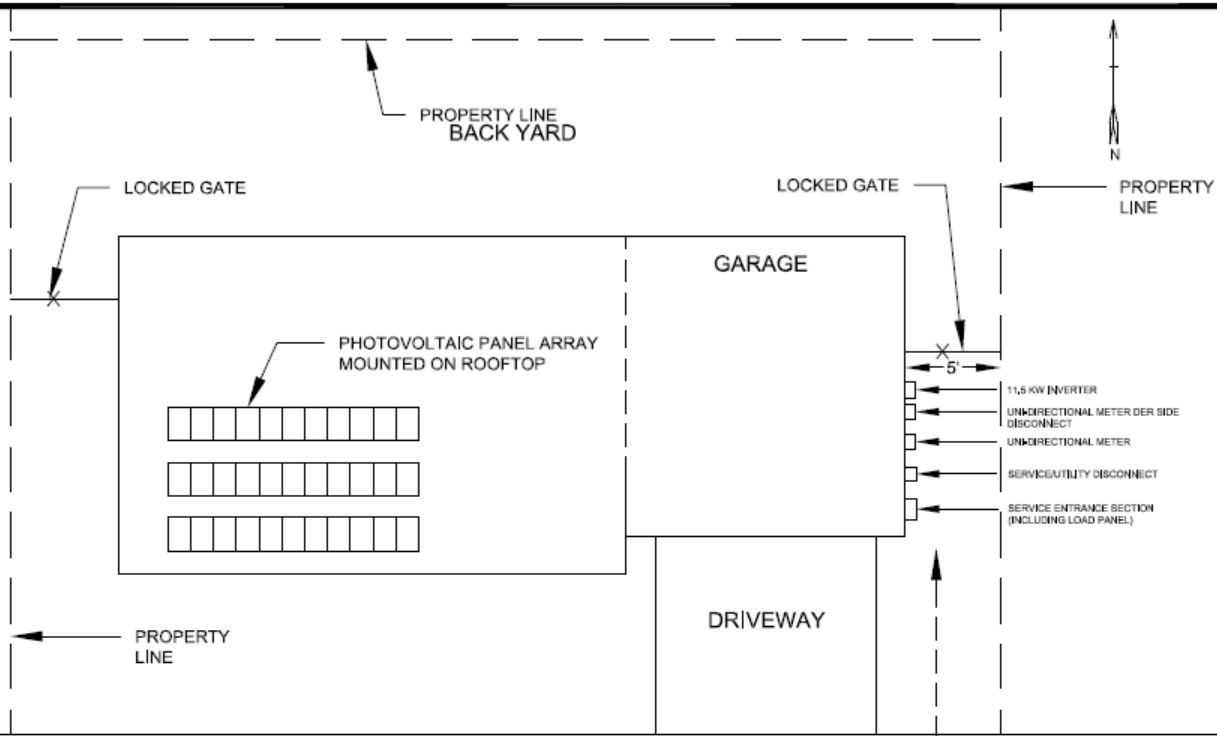
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1234 South Main Street Any City, Arizona 85123 Tel: 602-555-5555		ABC SOLAR COMPANY, INC.	
		SITE PLAN	
		11.5 KW AC PHOTOVOLTAIC SYSTEM	
		333 E. CACTUS BIRD RD, ANY CITY, AZ 85123	
APPROVALS	DATE	SIZE	DRAWING NO.
DRAWN ABC	06-29-05	B	0000-0005
CHECKED		SCALE	REV.
ENGINEER	02-13-06	NA	
REV. D			
ABC PROJECT #1111-9999			SHEET 3 OF 3

NOTE: UTILITY PERSONNEL REQUIRE COORDINATED ACCESS TO ALL DER SYSTEM COMPONENTS, SERVICE DISCONNECTS, METERING, AND SERVICE EQUIPMENT FOR SCHEDULED MAINTENANCE AND SAFETY INSPECTIONS. CUSTOMERS ARE RESPONSIBLE FOR ENSURING THAT ACCESS IS AVAILABLE AND MAY BE CONTACTED BY THE UTILITY TO ARRANGE SITE VISITS WHEN EQUIPMENT IS LOCATED WITHIN FENCED OR SECURED AREAS. EMERGENCY ACCESS TO THIS EQUIPMENT MUST BE AVAILABLE AT ALL TIMES.

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E. CACTUS BIRD RD.

APS 24-HR ACCESS

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		SITE PLAN	
		11.5 KW AC PHOTOVOLTAIC SYSTEM	
		333 E. CACTUS BIRD RD.	
		ANY CITY, AZ 85123	
APPROVALS	DATE	SIZE	DRAWING NO.
DRAWN FJG	02-13-26	B	0000-0005
CHECKED		SCALE	REV.
ENGINEER		NA	
REV.			
ABC PROJECT #1111-9999			SHEET 3 OF 3

Reminders

- Equipment location variances may be granted on a case-by case basis
 - Email renewables@aps.com
 - Photos help with application reviews
 - Ensure the photo includes the entire pathway, workspace, and grade below the equipment
- 400 A Meters require cutsheets
 - CT rated meter enclosures and custom switchboards require cutsheets when they are not on the approved list found on aps.com/esrm
 - Upload to PowerClerk under the Cut_Sheets attachment

Benefits of IEEE 1547-2018 Adoption & Advanced Inverter Settings

R. Danny Miranda



Highlights/Overview

- APS is adopting advanced inverter settings found within IEEE 1547-2018 for grid-support functions that align with best industry practices effective with the recently approved IRM.
- These settings have the potential to minimize the negative effects that high penetrations of Distributed Energy Resources (DERs) can have on the grid and allow more customers the opportunity to interconnect, and are a part of what makes Non-Exporting and Inadvertent Export systems possible.

Advanced Inverters & Grid-Support Functions

- Advanced (smart) inverters have the capability to monitor and respond to information (e.g., voltage, frequency) to maintain grid stability.
 - Adjust output to achieve longer operational time vs. reaching threshold and ceasing operation.
 - Ride through abnormal conditions.

IEEE 1547 & UL 1741-SB Certification



- UL 1741 is the industry standard for Inverter Safety
 - The tests which advanced inverters must pass to receive UL 1741 certification were designed to meet or exceed the requirements set forth by IEEE 1547-2018
- UL 1741-SB introduced interoperability conformance testing in accordance with IEEE 1547.1-2020, which established testing procedures for advanced inverter capabilities

UL 1741-SA & -SB Certification Differences



- Supplement B references IEEE Std. 1547.1-2020 to standardize certification and ensure testing covers the *full range* of allowable settings required by IEEE 1547-2018
 - SA-compliant devices are more narrowly certified to non-uniform performance requirements

UL 1741-SB

Over/Undervoltage Trip
Watt/VAR Mode
Constant VAR Mode
Tests

UL 1741-SA

Low/High Volt. Ride
Through
Low/High Freq. Ride
Through
Power Factor
Volt/VAR Mode
Frequency-Watt
Volt-Watt

IEEE 1547 & UL 1741-SB Certification (cont.)



- The previous revision of the APS Interconnection Requirements Manual (IRM), which had been approved Nov. 2022, originally stated APS had planned to require UL 1741-SB certified inverters alongside recommended settings July 2023.
 - However, SB-Certified inverters were not widely available, so APS continued to work with industry partners and manufacturers to continue approval of UL 1741-SA certified inverters
- The latest revision of the IRM, in effect as of 5/11, now requires SB certification.

Arizona Administrative Code (AAC) & Implementation of Advanced Settings

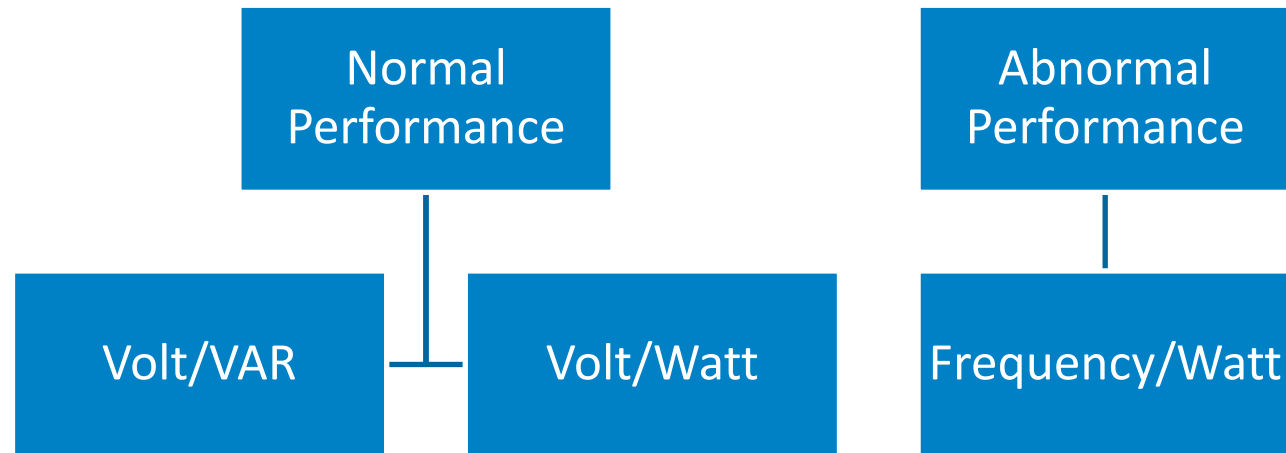
- [AAC Title 14, Chapter 2, Article 26, Section R14-2-2625 C.](#) allows for grid-support features to be implemented via Advanced Inverters upon mutual consent between customers and utilities
 - Volt/VAR
 - Volt/Watt
 - Fixed Power Factor
 - Soft-Start Reconnection
 - Frequency/Watt

APS Grid-Support Features

- Where we are:
 - Minimum Power Factor capabilities have been a long-standing requirement of the APS IRM, and Fixed Power Factor has been employed on a case-by-case basis.
- Where we're going:
 - With APS' adoption of IEEE 1547-2018, Volt/VAR will replace the Fixed Power Factor mode of operation.

APS Adoption of IEEE 1547-2018 Advanced Inverter Settings

- Adoption of default setting values found within Category B for Normal Performance & Category III* for Abnormal Performance



* Category III includes the IEEE 1547A-2020 Amendment

APS Adoption of IEEE 1547-2018 Advanced Inverter Settings (cont.)

- Proposed settings & documentation align with what is stated within AAC section R-14-2-2625, including a section for mutual agreement with customers

■ I warrant that the inverter(s) selected are in full compliance with IEEE 1547-2018 & UL 1741-SB, and will implement the default settings of Category B for Normal Performance & Category III for Abnormal Performance found within IEEE 1547-2018 & 1547a-2020, unless otherwise agreed upon with APS . *

Non-BES Voltage Schedule Letter

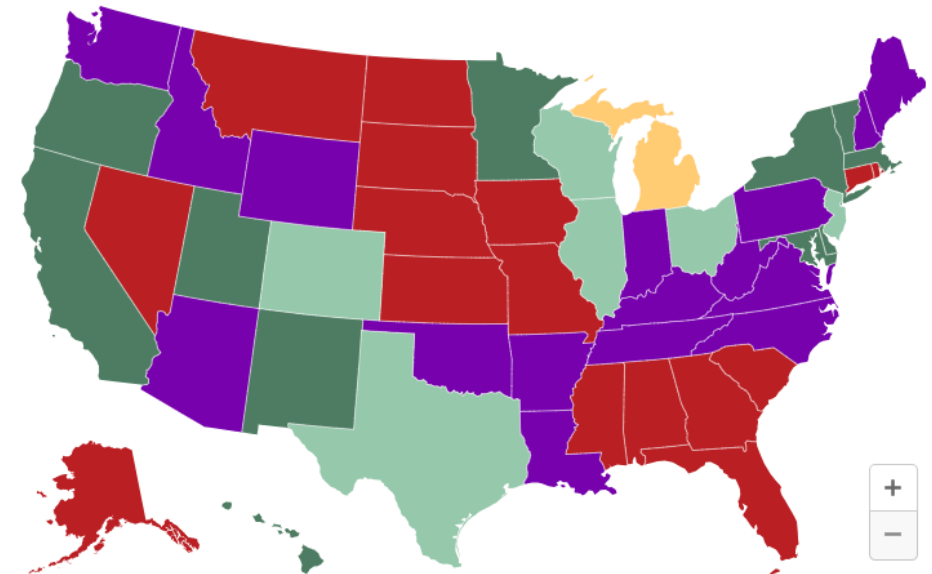
- APS Non-BES with POI voltage < 100kV & nameplate capacity \geq 10MW
- Accessible via [OASIS website](#)
- With regards to Inverter-Based Resources:
 - Default Operating Mode: Volt/VAR Control
 - Alternative Modes: Automatic Voltage Regulation, Power Factor Regulation
- Volt/VAR settings found in Attachment 1, other mode settings will be communicated upon approval

Benefits of implementing Advanced Inverter settings

- Follows Industry Best Practices
 - Survey conducted by IREC on Utility IEEE 1547-2018 adoption illustrates peer utilities have already adopted the standard, and more plan to in near future
 - Arizona
 - New Mexico
 - California
 - Hawaii

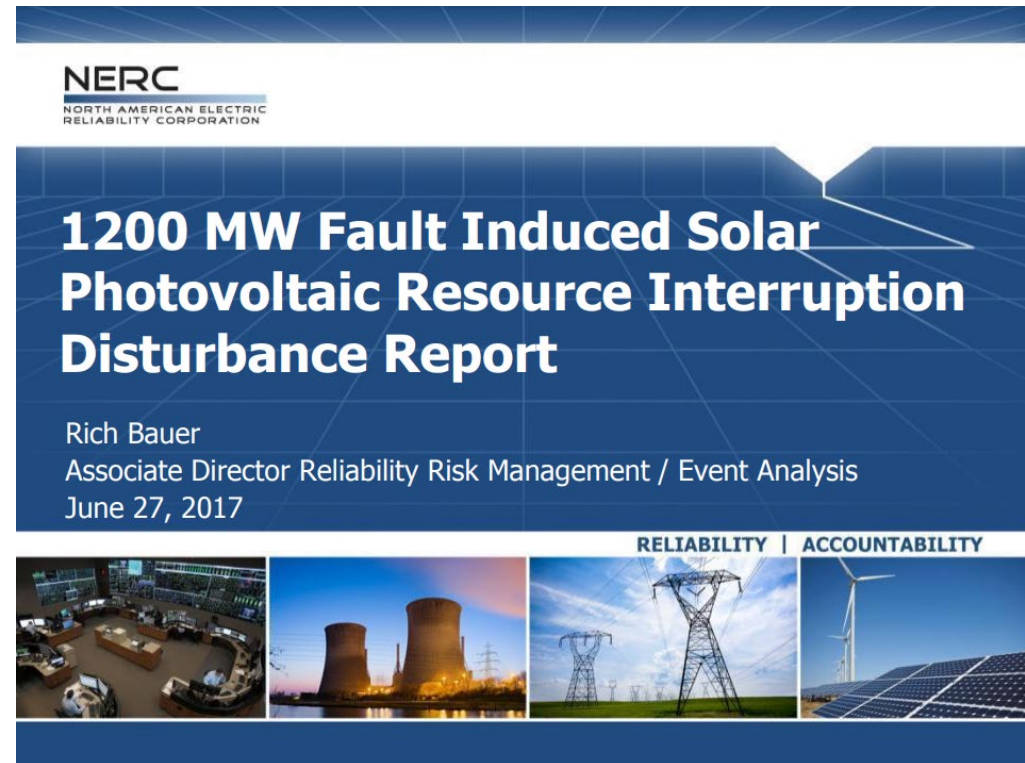
State Adoption Status

■ COMPLETE ■ INCOMPLETE ■ ONGOING ■ UNCLEAR ■ UTILITY-SPECIFIC



Benefits of implementing Advanced Inverter settings (cont.)

- IEEE 1547-2018 Category III Abnormal Performance functions were created as a mitigation in response to findings within [NERC Report](#)
 - “[...] is based on both BPS stability/reliability and distribution system reliability/power quality needs and is coordinated with existing interconnection requirements for very high DER penetration”



Benefits of implementing Advanced Inverter settings (cont.)

Customer Impacts:

- Implementing these settings will minimize effects a Generating Facility (GF) could have on power quality and allow for greater Hosting Capacities (HC)

- Will not impact design of GFs, but to meet expected kW output, utilize the ratio below:

$$- \frac{kW (nameplate)}{kVA (nameplate)} = 0.9, \text{ allows for a PF range of } +/- 0.9$$

Inverters < 10 MW (APS IRM Sec 12)

- Allow for more interconnections while also mitigating the potential need for line-side devices due to issues caused by GFs