

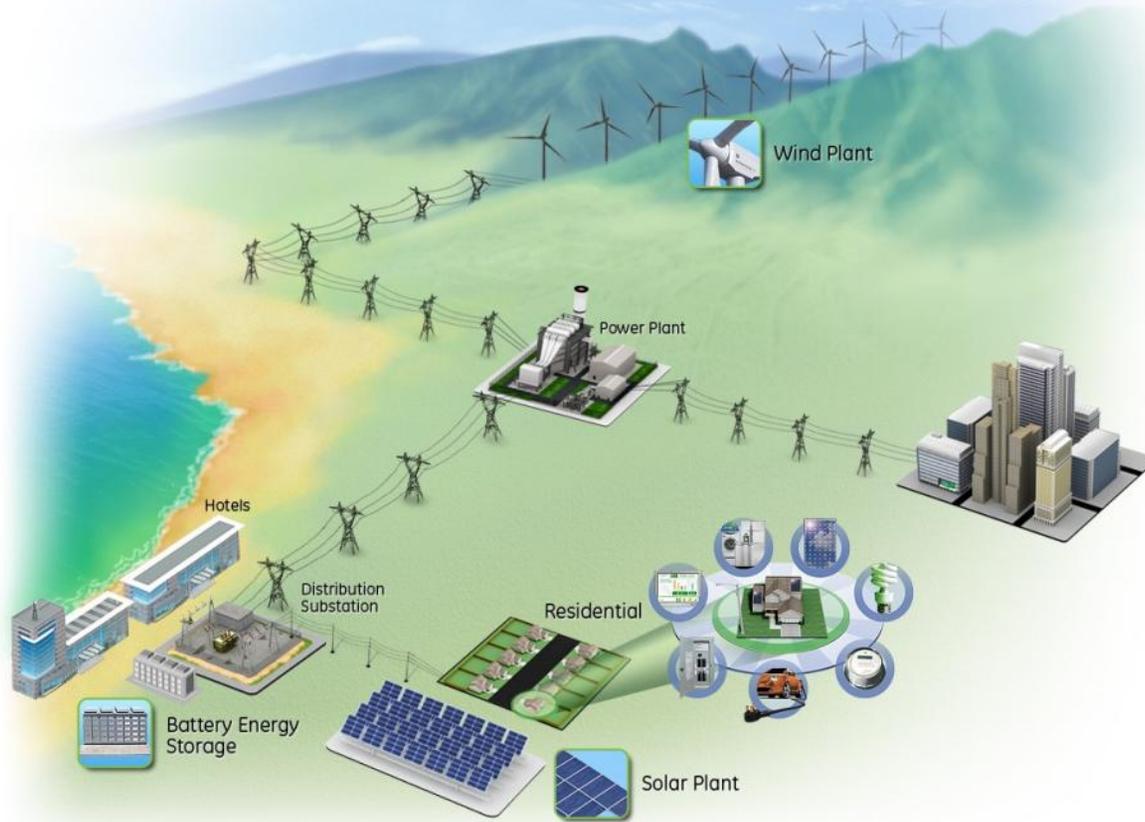
# Quantification of Risk of Unintended Islanding and Re-Assessment of Interconnection Requirements in High-Penetration of Customer-Sited Distributed PV Generation

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# What is islanding...



A condition when distributed generation is “on” and connected to the load but not to the bulk grid

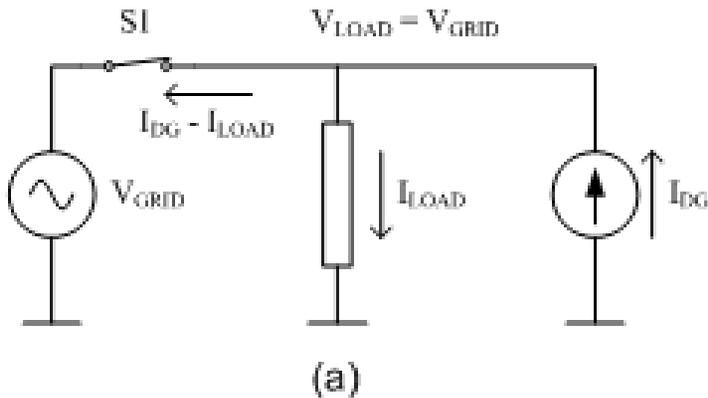
It arises after a switching action is taken to either clear a fault or reconfigure a circuit.

It must not persist – there is a safety risk to utility restoration crews.

UL1741 ensures that all certified inverters are able to detect an island condition and stop energizing the circuit.

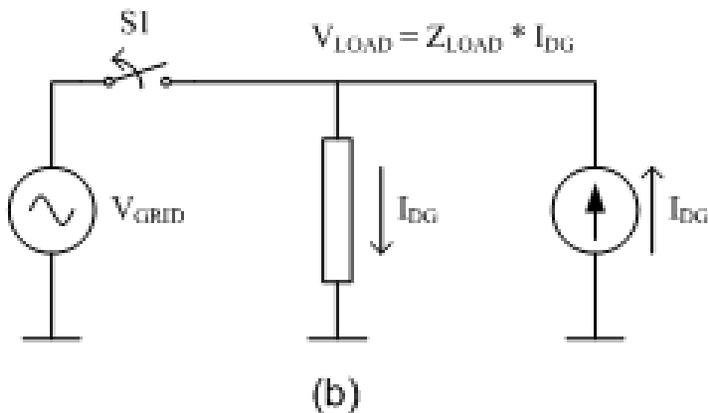
UL1741 is based on a pass/fail type-test, it leaves a significant gray-area...

# What are the Risks During Islanding...



During normal operation, a distribution circuit's voltage is defined by the power system.

Loads draw currents, PV inverters supply currents, but they both depend on the power system to define the voltage.



At the onset of islanding, the power system voltage is removed and the loads and PV inverters are left to themselves.

The electric transients between island formation and its eventual cessation are not well understood.

**There is a potential of damage to the load, to the utility equipment, or to the inverters. These risks are curbed by the 15% rule...**

# Project Team



**Principal Investigator**  
**Jovan Z. Bebic**  
 GE Energy Consulting

**GE Energy Consulting**  
 Program Management

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 Director

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**Jim Cavin**  
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 Principal Engineer  
 Distribution Engineering,  
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 Senior Program Manager  
 Policy & Integrated  
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**Pacific Gas and Electric Company**  
 Applied Technology  
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 Supervising Mechanical  
 Engineer

**David A. Bradley, P.E.**  
 Supervising Electrical  
 Engineer



# Project Tasks

## Task 1:

Project management, reporting, tech transfer and outreach

## Task 2

Data mining:

- 1) Selection of representative feeders
- 2) Aggregate load
- 3) Expected PV penetration
- 4) Correlation PV/Load
- 5) Load models

Load modeling in RTDS

- 1) Implementation
- 2) Benchmarking

## Task 3

Performance Testing:

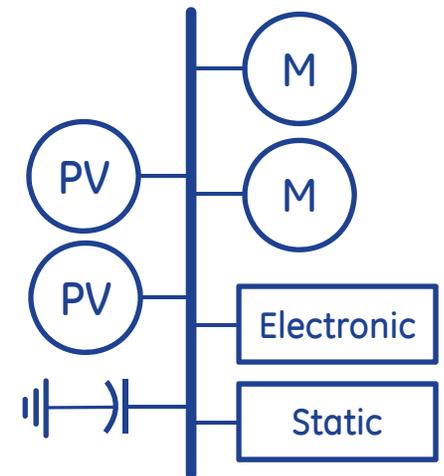
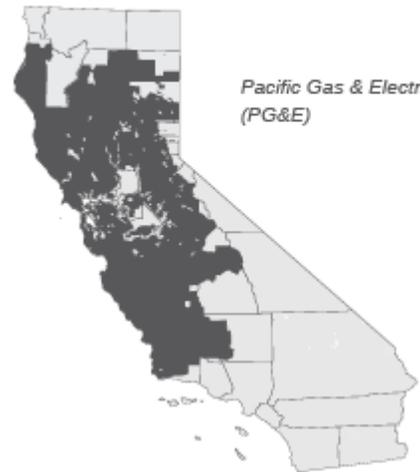
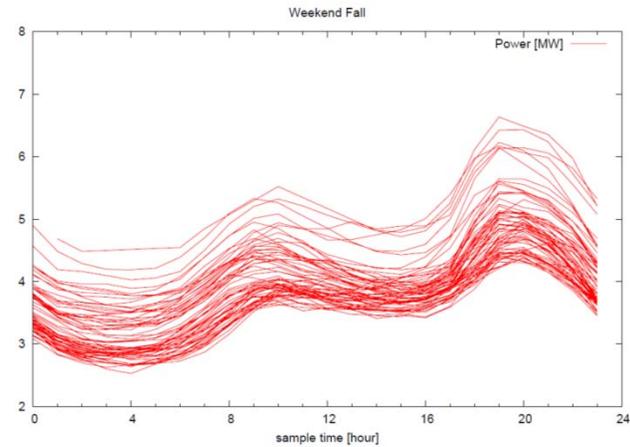
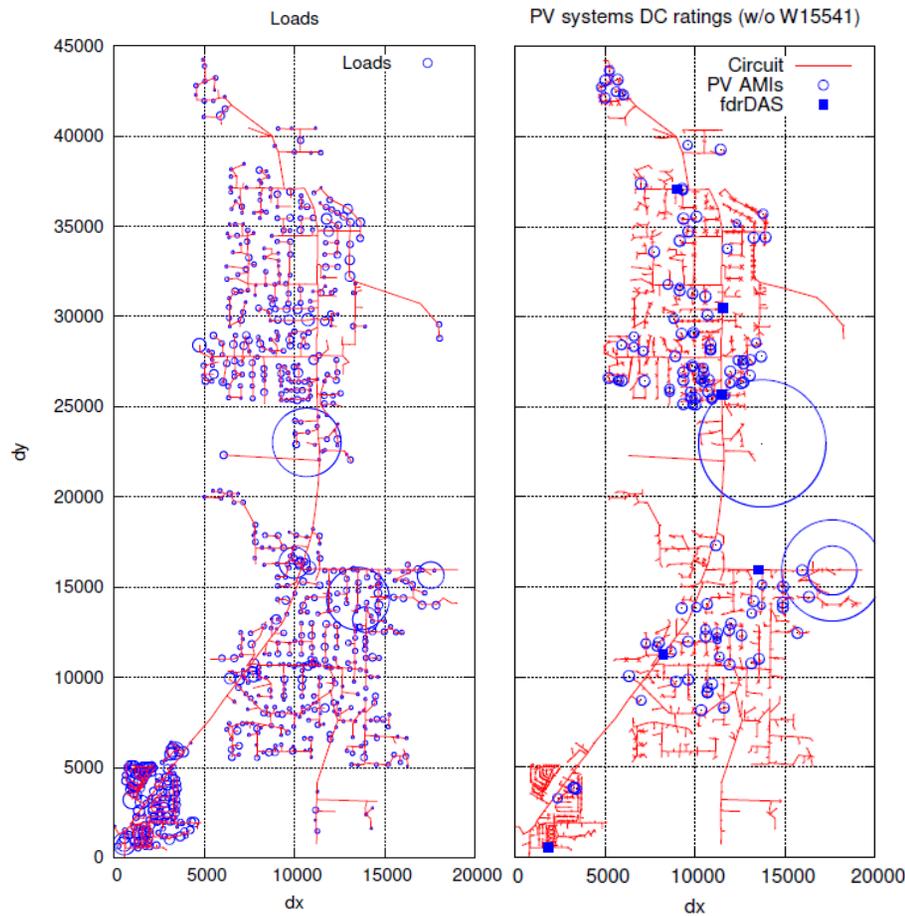
- 1) Test design & build
- 2) Power amplifier commissioning
- 3) Performance characterization
- 4) Testing

## Task 4

Evaluation of risk:

- 1) Analysis of test results
- 2) Weighting factors
- 3) Evaluation of PG&E's interconnection requirements in light of the findings

# Data Mining: Load & PV makeups, temporal balance, regional dependency => test plan

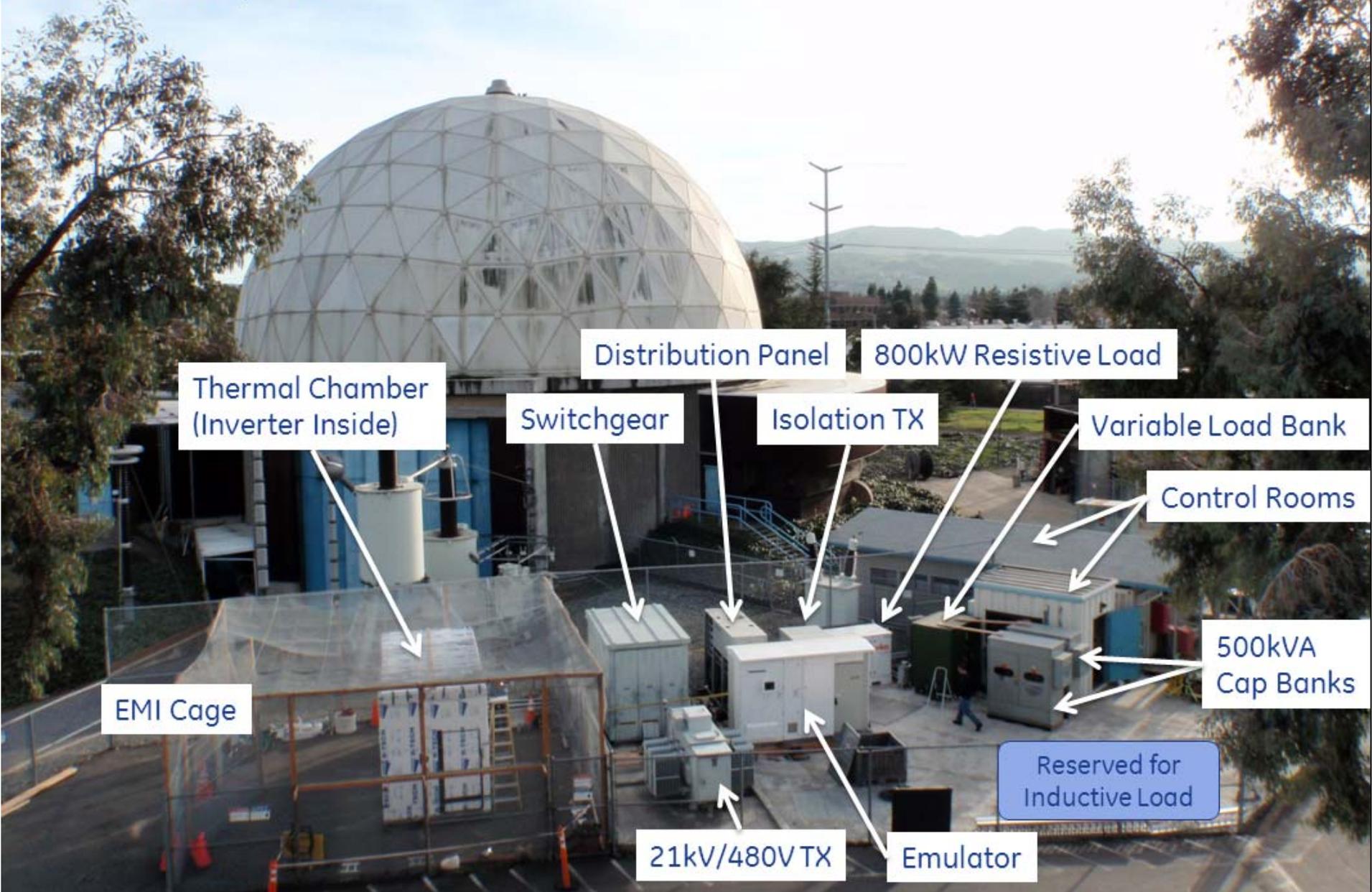


**Deliverables: Composite load models in RTDS; Test plan**



# PG&E Applied Technology Services

San Ramon, CA



Thermal Chamber  
(Inverter Inside)

EMI Cage

Switchgear

Distribution Panel

Isolation TX

21kV/480V TX

800kW Resistive Load

Emulator

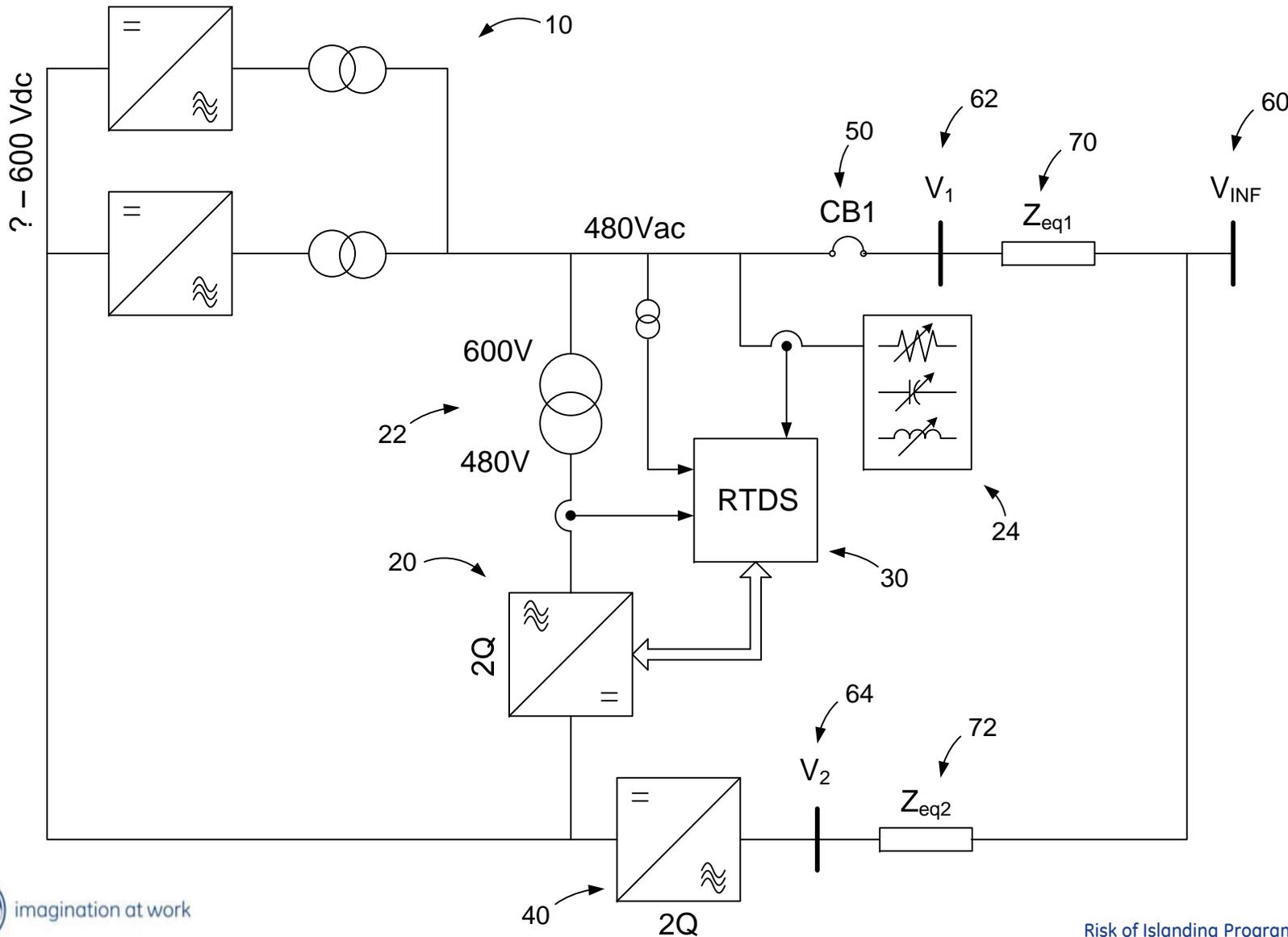
Variable Load Bank

Reserved for  
Inductive Load

Control Rooms

500kVA  
Cap Banks

# Testing - Inverter as a Power Amplifier



# Putting It All Together: Evaluation of Risks and Recommendations...

- Task 2: Delivers the probabilities of various combinations of load and PV becoming islanded
- Task 3: Delivers the risks of damage based on experimental results
- Task 4: Puts it all together – it prorates the risk of damage based on the probabilities of occurrence and provides recommendations for interconnect requirements



Thank you!



# Backup: Project Schedule

Task Description	Month																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
<b>1.0 Project management</b>	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
<b>2.0 Statistical analysis of PV generation - load balance</b>																								
2.1 Selection of representative circuits	█	█	█	█	█	█																		
2.2 Load and solar data analysis			█	█	█	█	█	█	█	█														
2.3 Development of dynamic load models						█	█	█	█	█	█	█												
<b>3.0 Aggregate PV Inverter Islanding Performance Testing</b>																								
3.1 Conceptual design of the test setup		█	█	█	█																			
3.2 Development of detailed test plans				█	█	█	█	█																
3.3 Test setup detailed design and build-up						█	█	█	█	█	█	█												
3.4 Data acquisition system (DAS) design and build						█	█	█	█	█	█	█												
3.5 Inverter conversion to power amplifier and interfacing to RTDS	█	█	█	█	█	█	█	█	█	█	█	█												
3.6 System commissioning													█											
3.7 Testing and collection of data														█	█	█	█	█	█					
3.8 Data analysis																█	█	█	█	█	█	█		
3.9 Test setup tear-down																						█	█	█
<b>4.0 Evaluation of Risks of Islanding and Recommendations for PG&amp;E Interconnection</b>																								
4.1 Evaluation of islanding risks																				█	█	█	█	
4.2 Recommending changes to PG&E interconnection process																						█	█	█