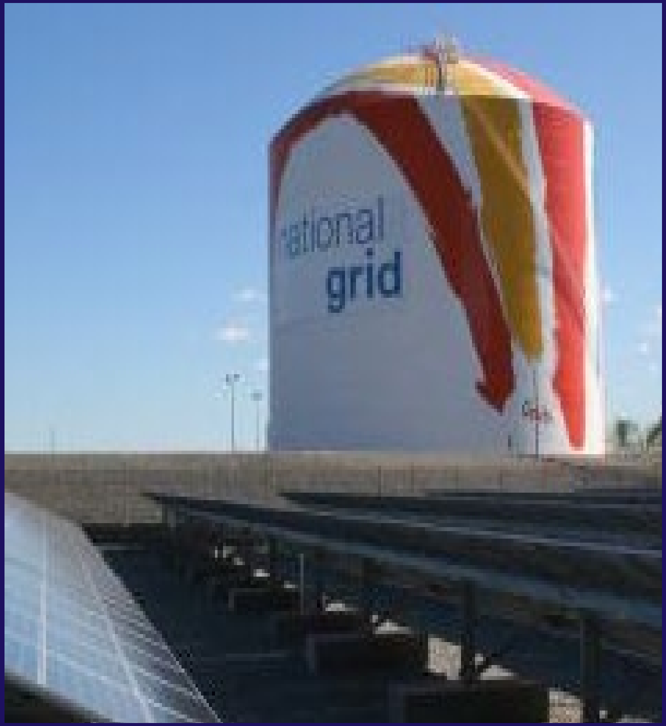
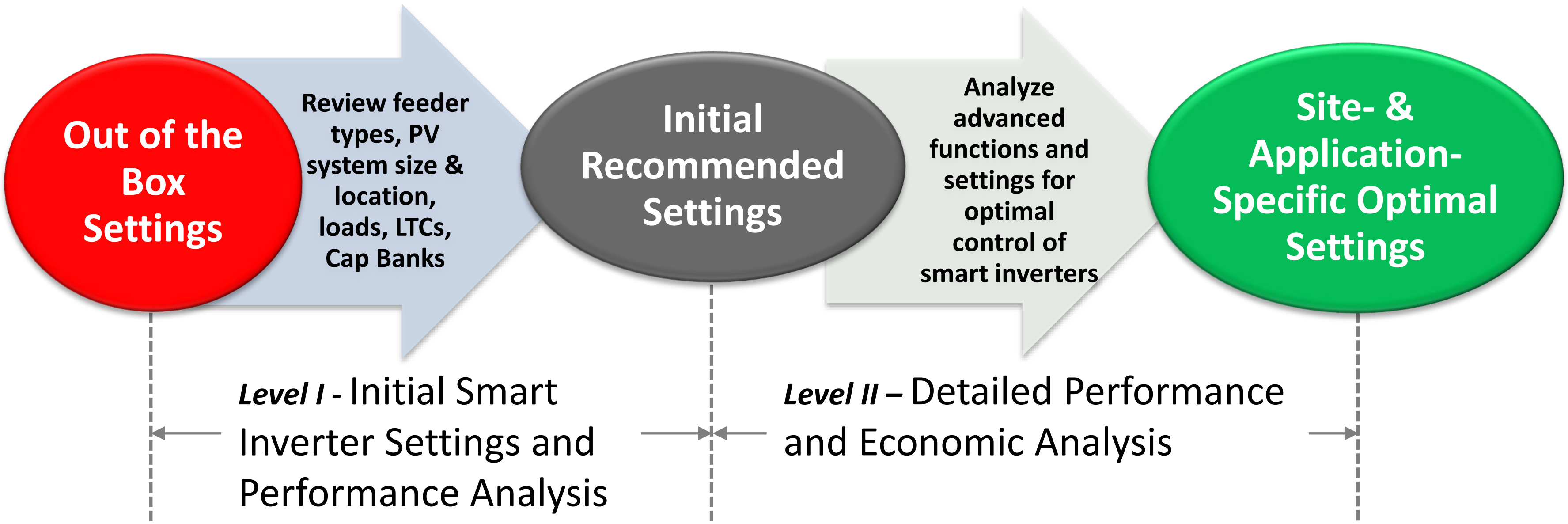
Beneficial Applications of Smart Inverter Technology- Project Update



Massachusetts Technical Standards Review Group (MTSRG)– 5/16/17

Samer Arafa

Project Phases



Level I: December 2016 - March 2018*.
Level II: Timeline TBD

*Original end date of Level 1 was December 2017, however the project was delayed to design a reliable metering solution.

Program Goals

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High Level Goals:

- Examine whether advanced solar inverters will be able to lower interconnection costs;
- Test advanced inverter capabilities, which may allow increased penetration of solar throughout the distribution system, including areas with voltage issues;
- Determine and quantify whether the smart inverters located in key geographical locations provide value to the operation of the electric distribution system.

Level 1 Objectives:

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Level 1 (current project) Objectives

- Establish best practices for the use of advanced inverter functionalities under different operational conditions.
- Identify ways to set the smart inverter functions such that the performance of other power sources does not adversely influence the circuit power quality.
- Evaluate the functionality of the control modes provided by the smart inverters.

Level 1 Task 1- Feeder Selection

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- Identify feeders with highest "Impact"
- Impact is made up of a group of conditions that were analyzed to evaluate the role that the additional Real Power and Reactive Power of the Advanced PV sites can have on improving the systems power quality.
- The issues analyzed were:
  - -Primary overvoltage
  - -Primary voltage deviation
  - -Regulator voltage deviation
  - -Primary undervoltage for generation
  - -Thermal limit for generation
- The higher the impact factor the more promising advanced Inverter features will possibly be at that given feeder.
- Five of the top impact feeders will be chosen for detailed analysis.
- National Grid used other impact factors not listed above, to allow testing on a wider variety of feeder conditions.

Site Address	Impact Factor
Patterson Rd. 1	1.35
Patterson Rd. 2	1.3
76 Groton Rd.	0.8
17 Kelly Rd.	0.8
26 Kelly Rd.	0.8
Blossom Rd. 1	0.6
Blossom Rd. 2	0.6
Cape Cod Lumber	0.4
438 Richardson Ave.	0.4
Carpenter Hill Rd. (29 Snake Hill Rd)	0.4
79 Old Upton Rd.	0.35
380 Frank Mossberg Dr.	0.325
24 Boutilier Rd.	0.175
19 Groton School Rd.	0.15
29 Oxford Rd.	0.1
755 Main St.	0
430 Stafford St.	0
50 Auburn Rd.	0

Level 1 Task 2-Metering Solution

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- The metering solution is designed to support:
  1-Power Quality Data with 1sec resolution.
  2-Collect Data during Voltage and Frequency Events

- Currently we are in the Prototype and Build stage.

- National Grid is expected to begin deployment end of June.

- Feeder Data Collection is planned to begin August 1st.

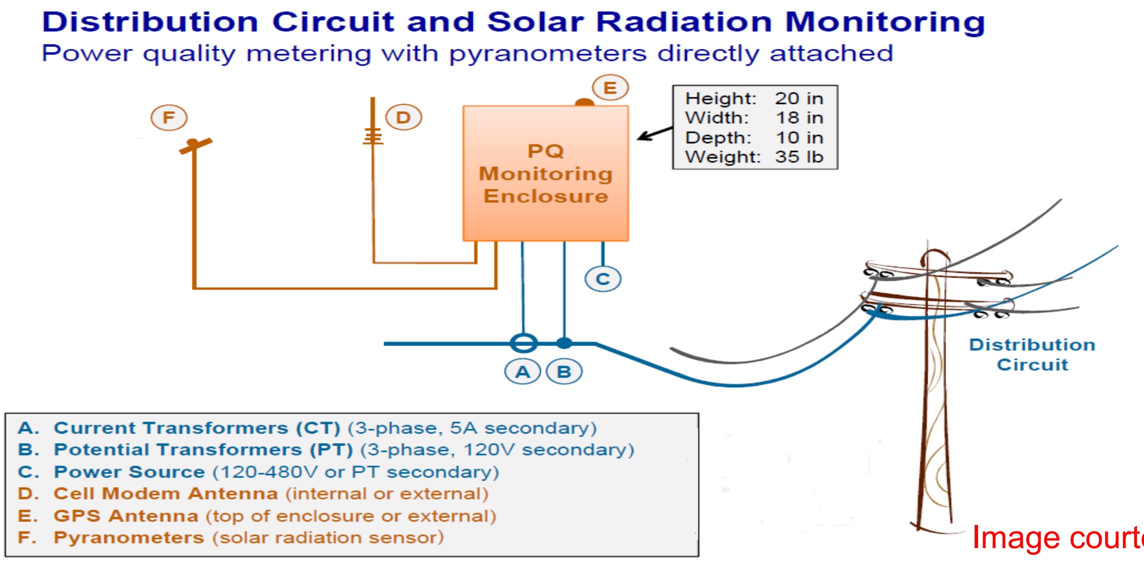

Image courtesy of EPRI

Level 1 Task 3-Test Plan

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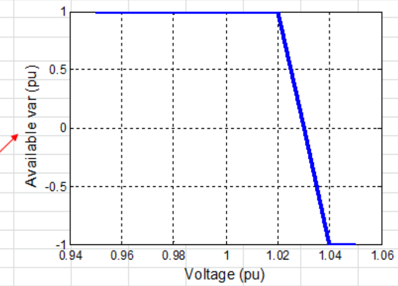
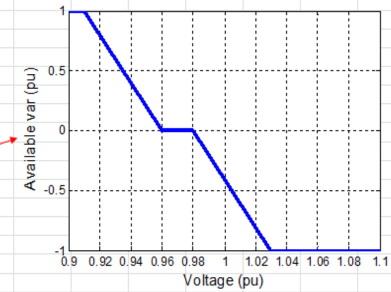
- Features chosen for the test plan were based on EPRI's and National Grid's experience from prior projects.
- Each Feeder will get its unique settings based on the results of the feeder impact study.
- Voltage and Frequency Ride Through events will be captured if they occur but they won't be intentionally created.

Utility/Project Name

Adv. Function	Day #	Date	Setting
PF	1		0.96 Absorbing
	2		1
	3		0.96 Absorbing
	4		1
	5		0.96 Absorbing
	6		1
	7		0.96 Absorbing
Volt-Var	1		(1.02, 1), (1.03,0), (1.03,0), (1.04, -1)
	2		volt-var inactive
	3		(1.02, 1), (1.03,0), (1.03,0), (1.04, -1)
	4		volt-var inactive
	5		(1.02, 1), (1.03,0), (1.03,0), (1.04, -1)
	6		volt-var inactive
	7		(1.02, 1), (1.03,0), (1.03,0), (1.04, -1)
PF	1		0.93 Absorbing
	2		1
	3		0.93 Absorbing
	4		1
	5		0.93 Absorbing
	6		1
	7		0.93 Absorbing
Volt-Var	1		(0.91, 1), (0.96,0), (0.98,0), (1.03, -1)
	2		volt-var inactive
	3		(0.91, 1), (0.96,0), (0.98,0), (1.03, -1)
	4		volt-var inactive
	5		(0.91, 1), (0.96,0), (0.98,0), (1.03, -1)
	6		volt-var inactive
	7		(0.91, 1), (0.96,0), (0.98,0), (1.03, -1)
PF	1		0.98 Absorbing
	2		1
	3		0.98 Absorbing
	4		1
	5		0.98 Absorbing
	6		1
	7		0.98 Absorbing
Volt-Var	1		(0.97, 1), (1.01,0), (1.01,0), (1.05, -1)
	2		volt-var inactive
	3		(0.97, 1), (1.01,0), (1.01,0), (1.05, -1)
	4		volt-var inactive
	5		(0.97, 1), (1.01,0), (1.01,0), (1.05, -1)
	6		volt-var inactive
	7		(0.97, 1), (1.01,0), (1.01,0), (1.05, -1)
	42 Days		





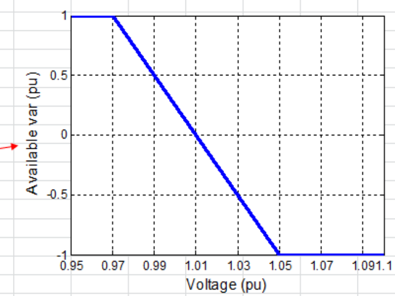


Image shows default test plan prior to any feeder specific adjustments.

Level 1 Task 3-Power Factor Settings

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- The optimum settings for power factor for a feeder are highly dependent on its unique characteristics.
- Items such as PV generation and X/R ratios result in each feeder getting customized settings.
- Adjustments were also made to correct transformer reactance and losses.

Site Address	Nodes	R1 (primary)	X1 (Primary)	Transformer R	Transformer X	X/R	Adjusted X/R	Power Factor
17 Kelly Rd.	4503(pri)	1.802	4.152	1.431	5.724	2.303	2.670	0.94 (absorbing)
26 Kelly Rd.	4489 (pri)	1.826	4.171	1.431	5.724	2.284	2.646	0.94 (absorbing)

Adjusted Power Factor setting for 17 & 26 Kelly Road PV sites, Table courtesy of EPRI

Level 1 Task 3-Volt-VAR Settings

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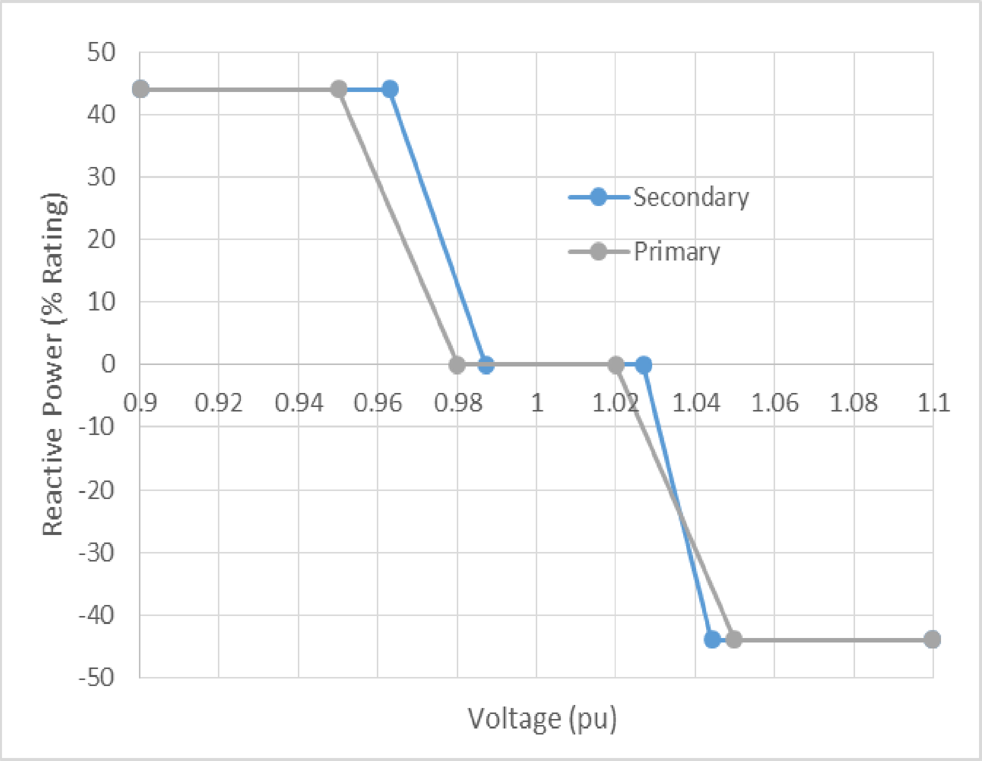
- Volt-VAR settings for a feeder are dependent on several internal and external factors

- Differences between Peak Load and off Peak Load as will as PV site distance from the feeder are among them.

- Furthermore, location of the site metering should also be considered as shown in the Volt-VAR curve on the right.



Adjusted Volt-VAR curve for 17 & 26 Kelly Road PV sites, Image courtesy of EPRI

Level 1 Task 4-6

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- Work on Tasks 4, 5 and 6 will begin once sufficient data has been collected (estimated 12 months from now)
- Task 4 will analyze detailed data of 5 high impact feeders to evaluate the benefits the features and settings had on the distribution voltage.
- Task 5 will identify additional specific application testing for Level 2.
- Task 6 will create a project report with lessons learned and recommendations to transform the findings for real life applications.

Potential Future Work

Level II (Potential Future Project)

- Evaluate strategies for reducing the aggregate interconnection costs through advanced inverter features.
- Identify ways that smart inverters may facilitate additional hosting capacity.
- Evaluate effectiveness of various smart inverter functions for distribution system benefits (e.g., reliability, safety, efficiency, power quality, asset life, capital spending deferral).
- Evaluate distribution system level economic benefits when utilizing the features of a smart inverter compared to a conventional inverter.

Questions

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