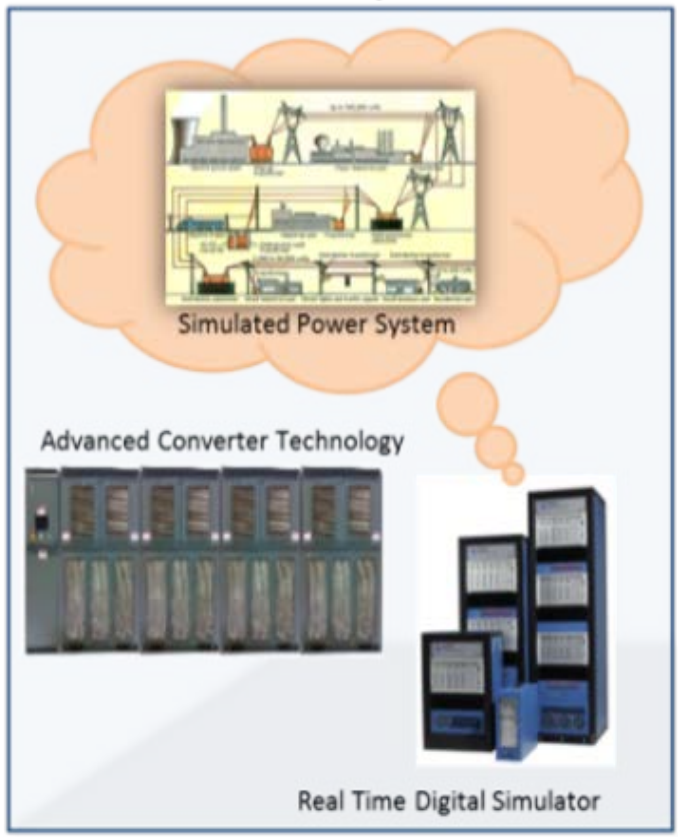
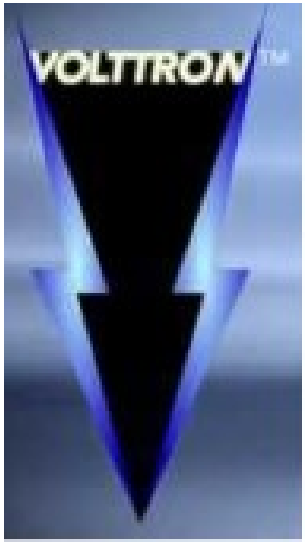
Distribution Transformer Data, Testing, and Control

2017 Building Technologies Office Peer Review





U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start Date: August 2016

Planned End Date: September 30, 2017

Key Milestones:

1. Data report complete (4/30/17)
2. Transformer testing report complete (9/30/17)
3. Control scoping report complete (6/30/17)

Budget:

Total Project $ to Date:

- DOE: $140,000
- Cost Share: none

Total Project $:

- DOE: $695,000
- Cost Share: none

Key Partners:

Savannah River National Laboratory (SRNL)
Oak Ridge National Laboratory (ORNL)
Santee Cooper
Clemson University *e*GRID team
Pacific Northwest National Laboratory (PNNL)

Project Outcome:

- Compile extensive data describing distribution transformer performance for both traditional silica-steel and advanced amorphous steel cores
- Develop and explore alternative control strategies that could enhance transformer efficiency

Purpose and Objectives

Problem Statement: Distribution transformer losses account for 2–3% of U.S. generated electricity and no-load losses represent approximately 25% of these losses. An objective of this project is to reduce no-load losses of distribution transformers by addressing the market barriers for adoption of the most advanced commercially available transformer technologies and materials, as well as to reduce transformer load losses by designing and developing dynamic transformer controllers to more effectively manage efficiency and lifetime performance.

Target Market: Transformers deployed in utility distribution systems and at buildings.

Target Audience: Transformer manufacturers, utilities,

Impact of Project:

- Adoption of more efficient transformers could reduce no-load losses by 60%
  - Project will assemble data addressing market barriers that impede this adoption
- Dynamic control and coordination of transformers and building loads could reduce losses by 10%
  - The project will scope control strategies that might deliver this benefit

Approach

- Collection of 20 years of field data enabling comparison of performance and ownership costs for traditional silica-steel (SiFe) core transformers vs. amorphous metal distribution transformers (AMDT)
  - Enabled by the close relationship between SRNL, Clemson, and Santee Cooper
- Laboratory testing of eight transformers (4 SiFe, 4 AMDT) offered to the project by Santee Cooper
  - Saves about $90K previously planned for procurement of transformers and enables testing to be completed this FY
- Definition of potential control strategies that might improve transformer performance, scoping analyses to determine the potential benefit of these strategies, readying the most promising strategies for possible implementation on the VOLTTRON platform

Progress and Accomplishments

- Defined and reviewed test plan for execution at the *e*GRID lab
  - Establishes functional acceptance, efficiency baseline, sweeping tests of efficiency/harmonics, and degradation over time
- Santee Cooper offering 8 transformers to the project
  - Significantly reduces project cost
  - Enables project to meet available testing window at the *e*GRID lab
- Santee Cooper sharing 20 years of performance and cost data
- Identified six innovative control strategies to be scoped and analyzed

Project Integration and Collaboration

Project Integration:

1. SRNL collect data from utilities (Santee Cooper, Duke Energy, etc.)
2. Santee Cooper will select transformers to be shipped to the *e*GRID center, then SRNL will work with *e*GRID staff to perform tests, with support from ORNL
3. PNNL and ORNL will conduct scoping analyses concerning controllers and will create a single report for DOE

Partners, Subcontractors, and Collaborators:

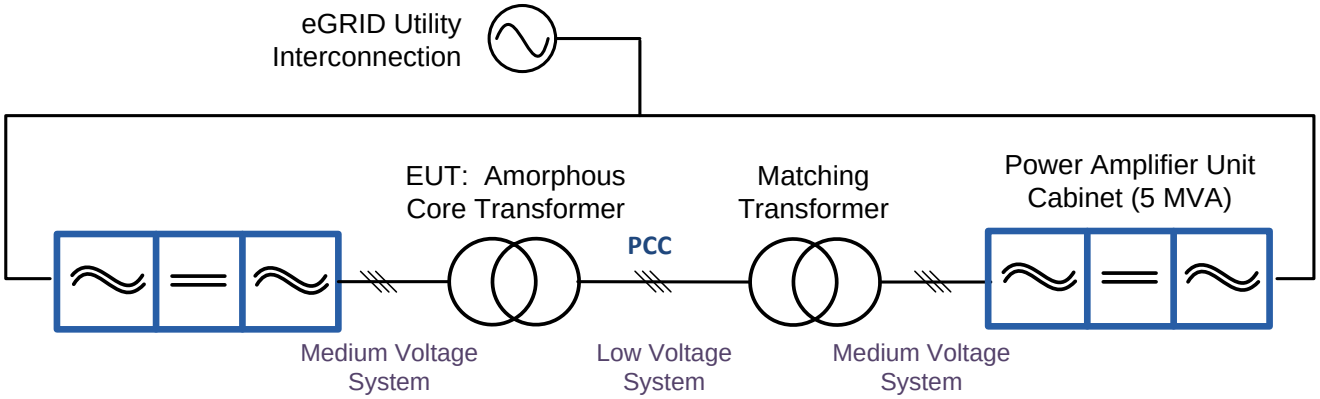
Partner	Role
PNNL	Project coordination, control strategy development & analysis
SRNL	Data collection, develop testing specifications
ORNL	Testing consultation, control strategy development & analysis
Santee Cooper	Data sharing, testing consultation, 8 transformers
Clemson *e*GRID	Transformer testing

Next Steps and Future Plans: Data Collection

Collect Data from Utilities

- Some electric utilities already using amorphous metal distribution transformers
  - Field performance data can be collected and analyzed
  - Data can be used to inform appliance and equipment standards and utilities wishing to deploy more advanced distribution transformers
- Data will be collected from utilities (Santee Cooper, Duke Energy) regarding recent historical experiences with distribution transformers
  - This data will include the following:
    - Specifications of amorphous metal distribution transformers (AMDT) purchased
    - Installation locations and quantities of AMDTs deployed in their electrical grid
    - Deployment and usage comparisons of AMDTs to traditional core transformers
    - Quantities and failure modes of AMDTs removed from service
- Report on transformer utilization and performance data

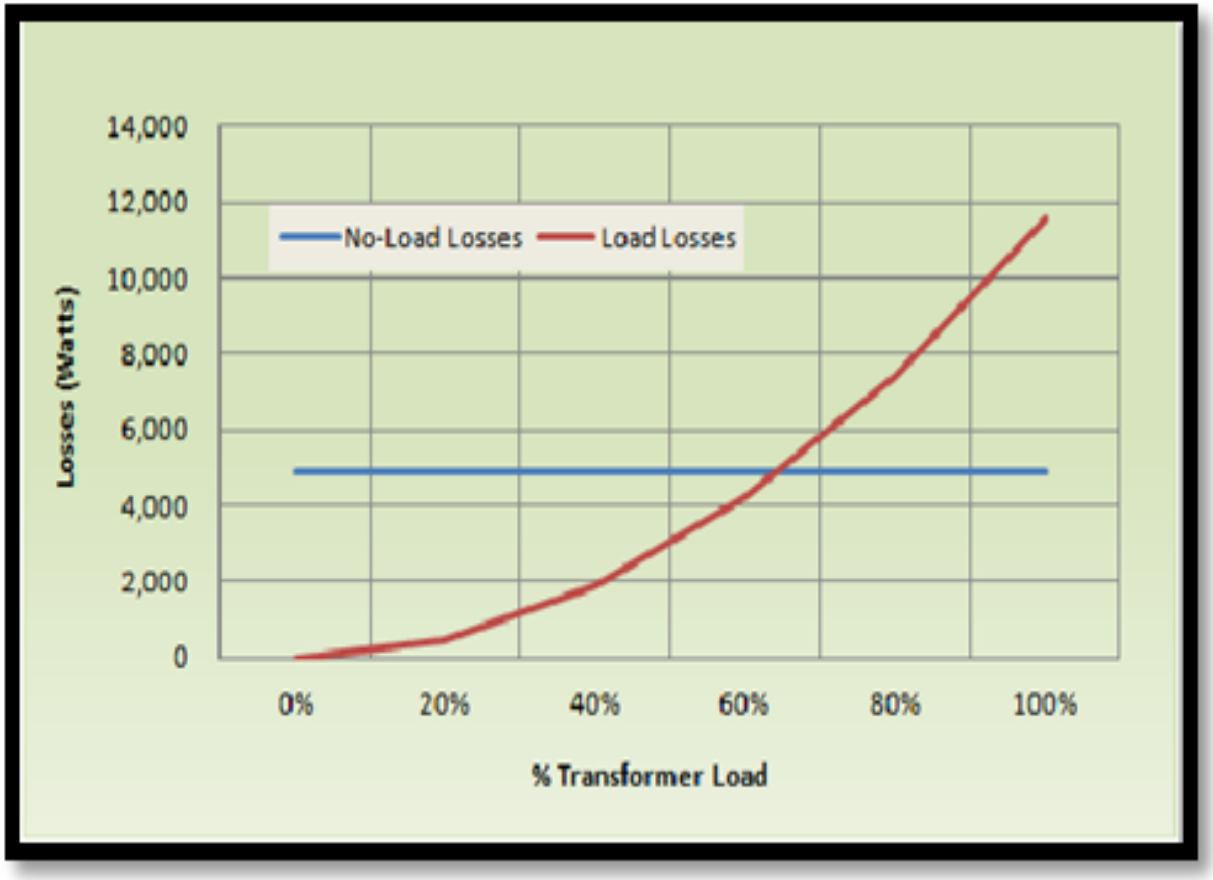
Next Steps and Future Plans: Transformer Testing



- Acquire and install distribution transformers at the *e*GRID Center
- Perform side-by-side tests of four SiFe and four AMDT units to compare the relative performance of the different cores (pad- and pole-mount units)
  - Results will determine the quality, reliability, and performance of both types of cores, and potentially increase the efficiencies of future distribution transformers
- Report on
  - Test plan and test setup
  - Detailed analysis of the sets of transformers purchased for testing
  - Results from tests performed
  - Analysis and recommendations based on the test results

Next Steps and Future Plans: Control Strategies

PNNL and ORNL will perform **scoping analyses** in **six topic areas** to determine benefits that could be gleaned through innovative control of distribution transformers and the loads that they serve



Scoping Analyses

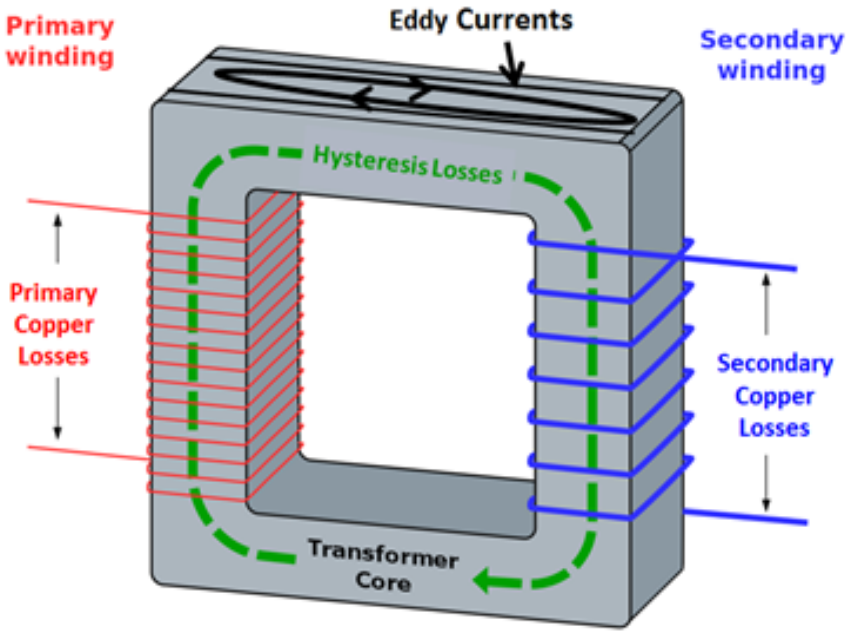
- Mitigate effects of unbalanced phases
- Increase effective part-load efficiency
- Flatten load

Each of these takes advantage of a nonlinear relationship between load and no-load transformer losses

Next Steps and Future Plans: Control Strategies (2)

Scoping Analyses (continued)

- Protect transformer lifetime
- Mitigate effects of poor power quality
- Address how solid-state transformers fare in light of these control objectives



- Transformer degradation is a function of time, electrical load, and temperature
  - If we have a good model of this relationship, a transformer's life might be extended
- Poor power factor and harmonics subject a transformer to electrical currents that heat up the transformer without contributing to useful power transfer

REFERENCE SLIDES

Project Budget

Project Budget: $900K of funding received in Spring of FY2016

Variances: Project is currently operating on FY2016 carryover

Cost to Date: Cost to date in FY16 totaled $76K. Cost through February 2017, totals $112K. $305K is currently committed to SRNL.

Additional Funding: Not applicable

Budget History					
FY2016 (past)		FY2017 (current)		FY2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$900K	$0K	$0K	$0K	$0K	$0K

Project Plan and Schedule

Project Schedule													
Project Start: June 2016		Completed Work											
Projected End: Sept. 2017		Active Task (in progress work)											
		Milestone/Deliverable (Originally Planned)											
		Milestone/Deliverable (Actual)											
	FY2016				FY2017				FY2018				
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work													
Q1 Milestone: T5: Confirm utility participation in the project team													
Current/Future Work													
Q3 Milestone: Task 1.2 – Complete a report on transformer utilization and performance data													
Q2 Milestone: Task 2.1 – Finalize test plan													
Q3 Milestone: Task 2.2 – Eight distribution transformers purchased from Santee Cooper													
Q3 Milestone: Task 2.3 – Distribution transformers installed at eGRID Center													
Q3 Milestone: Task 3.7 – Report on Task 3													
Q4 Milestone: Task 2.5 – Complete report summarizing to DOE data collected and analysis of results													