U.S. DEPARTMENT OF
ENERGY
Office of Electricity

Design, Deployment, and Characterization of the World's First Flexible Large Power Transformer

TRAC Program Review

US Department of Energy, Office of Electricity

Presented at Oak Ridge National Laboratory

Oak Ridge, TN

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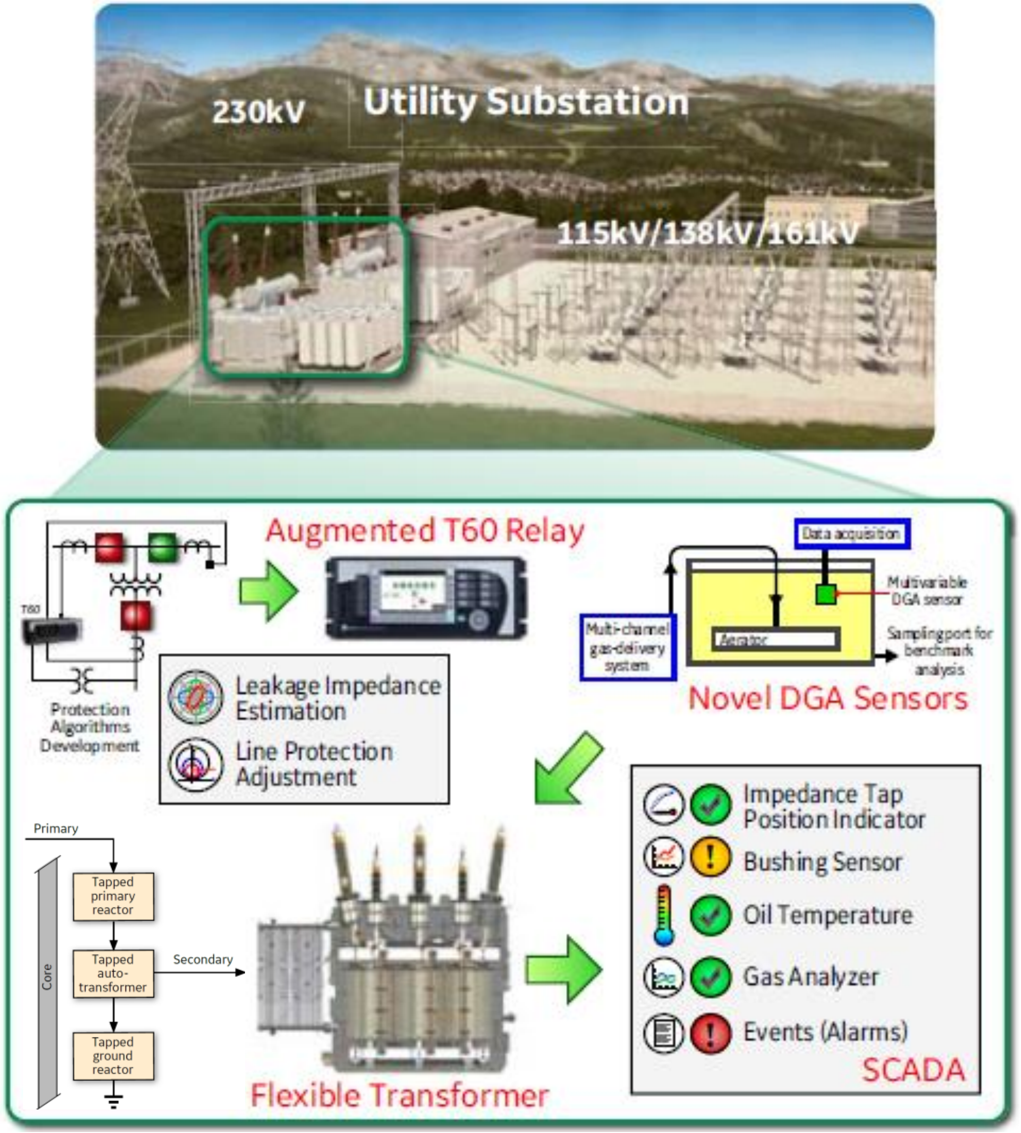
Tuesday, August 13 2019

Project Overview

- Project summary:
  - develop, test and deploy a 60 MVA, 230 kV to 161/138/115 kV prototype of a flexible large power transformer which allows its short-circuit impedance to be adjustable online within a wide range (4% to 18%)
- Total value of award: $2.97MM ($2.37MM federal + $0.6MM cost share)
- Period of Performance:
  - 10/1/2019 – 9/30/2021
- Project team: GE Research and Prolec GE



Context concerning the problem being addressed

- Large Power Transformers (LPTs) in today's practices are not flexible:
  - Can't replace each other unless identical (production per design ratio ~1.3 - Source: DOE)
  - Provide very limited support to the grid (voltage regulation)
  - More flexible LPTs will enable a more flexible grid as required by higher penetration of renewables energy sources in a constantly evolving grid
- Average age of U.S. populations of LPTs ~38 years, 70% being 25 years and older (Source: DOE)
  - Untimely outage of many LPTs will pose serious risks to the grid operation and nation's security.
  - High inventory costs associated with large spare inventory
- No environmental, human health or wellness impacts as using same insulating and assembly material found in conventional LPTs

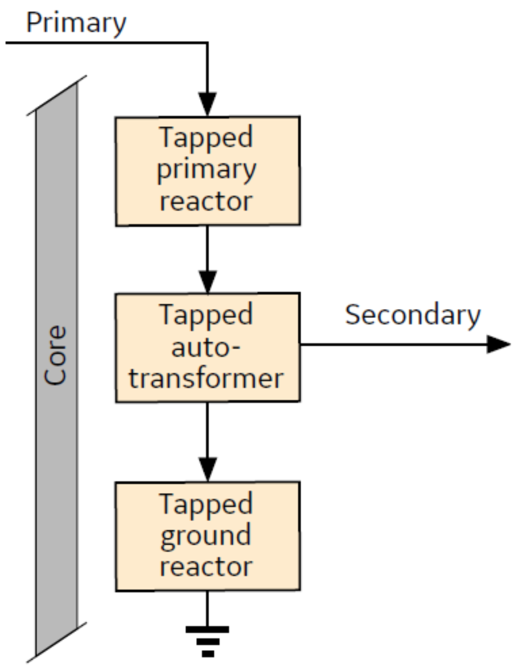
State of the art approaches for addressing the problem

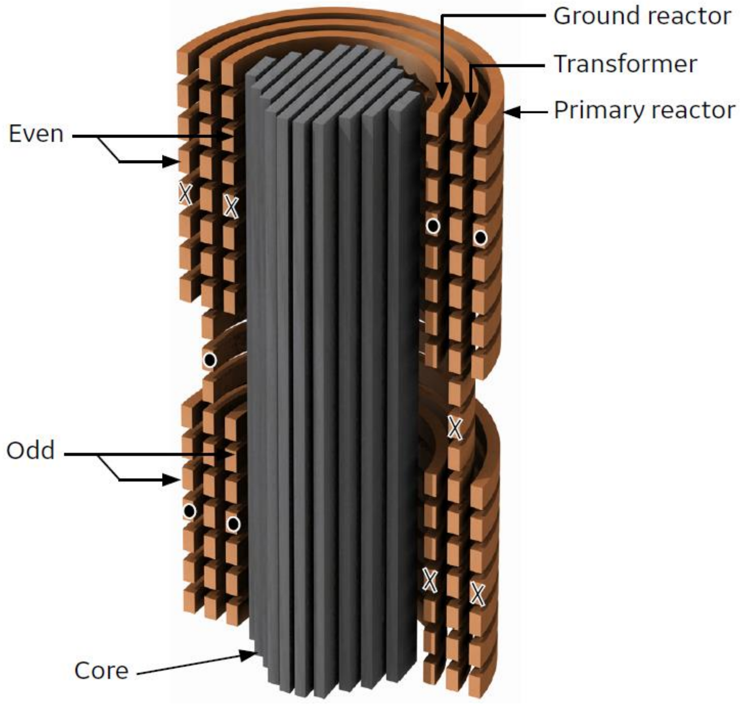
- Solid-state transformers:
  - <u>Merits</u>: allows a high flexibility; enables a more compact substation design by combining all ancillary equipment
  - <u>Drawbacks</u>: complexity, higher cost of ownership, reduced reliability, limited flexibility as spare

- Transformers + reactors:
  - <u>Merits</u>: simple design, already proven design
  - <u>Drawbacks</u>: large footprint, higher cost of ownership, unpractical for spare coverage

Uniqueness of the proposed solution

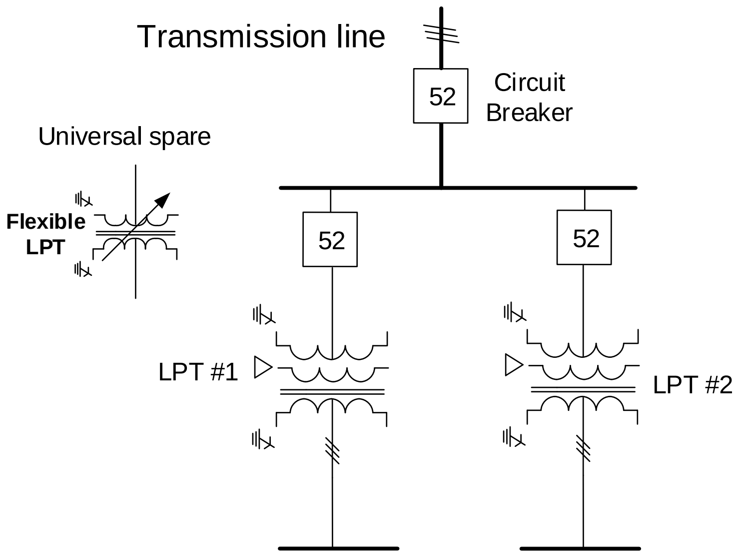
- A LPT that enables online adjustable short-circuit impedance in any of its voltage configuration.
- Using only conventional material (insulation, conductors, assembly, etc)

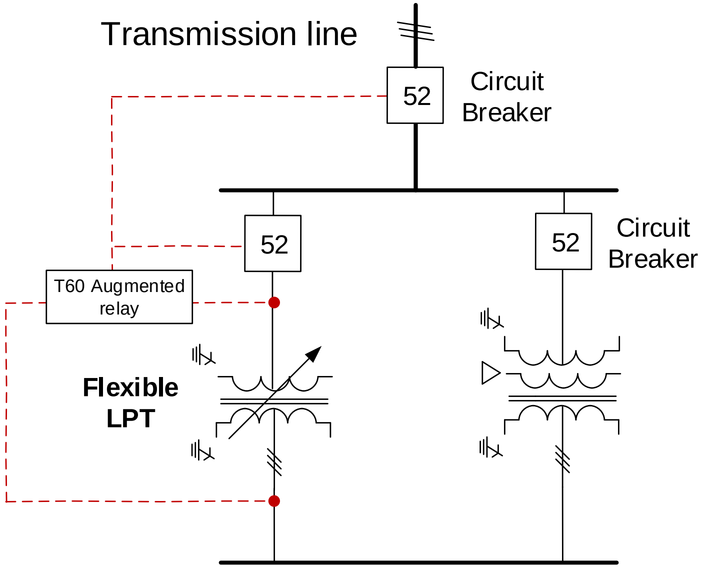


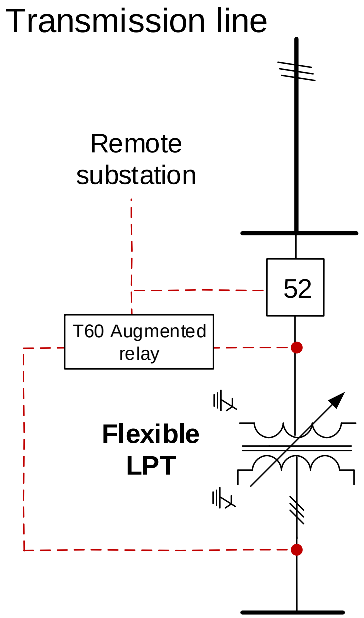


Significance of the results, if successful

- LPTs inventory and associated costs can be significantly reduced
  - One flexible LPT can provide spare coverage for multiple LPT units
- This technology will enable control of power sharing between paralleled LPTs, control of power flow and reactive power for short transmission lines
- This technology will enable short-circuit management at the substation







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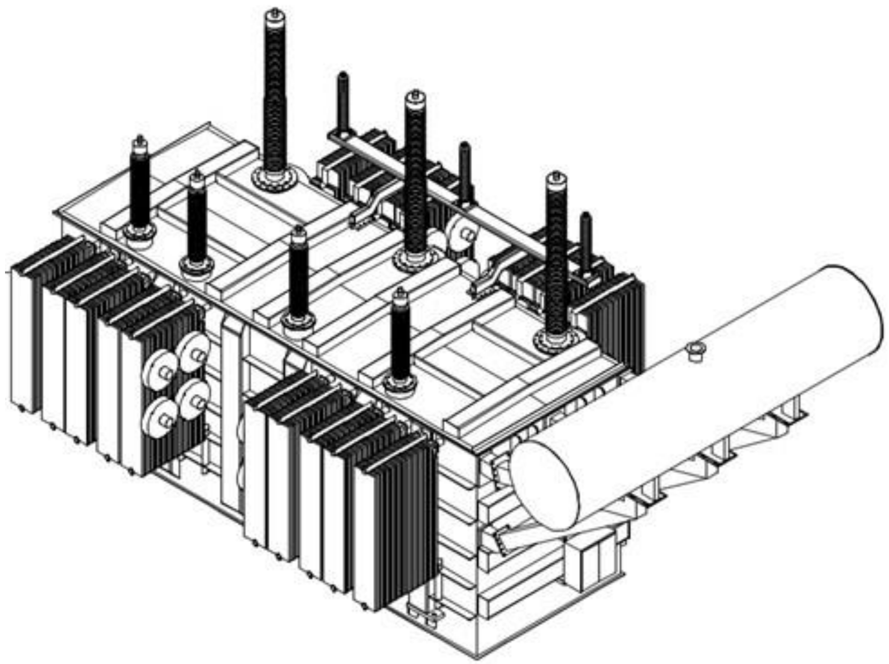
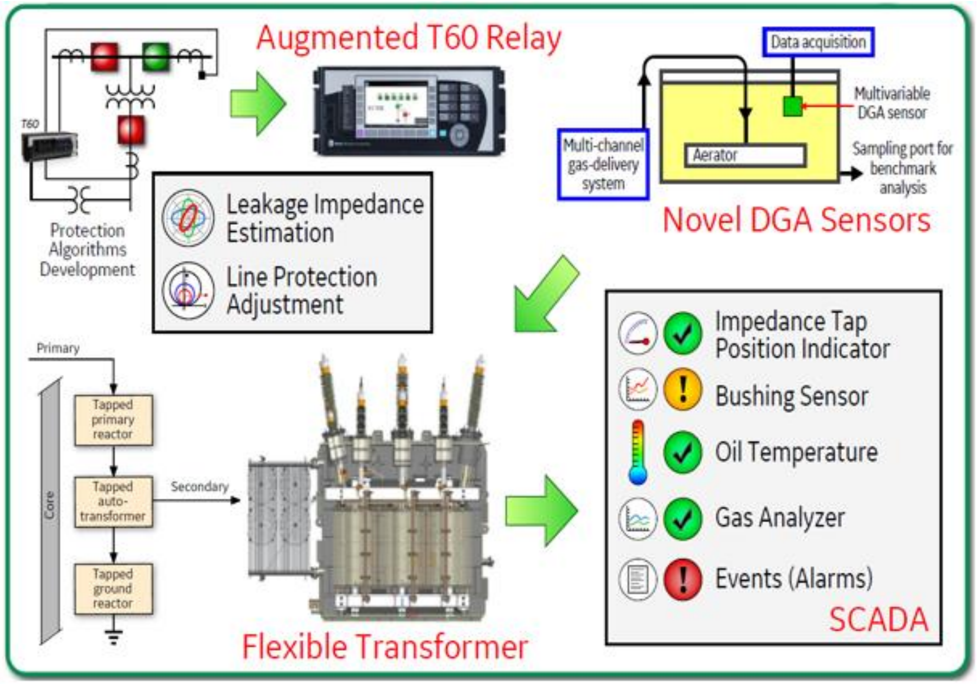
Specific research questions being addressed





- Can the flexible LPT design meet IEEE.C57.12.90 requirements?
- Can the flexible LPT footprint be within 20% of similarly sized regular LPTs?
- Can the short-circuit impedance be accurately measured online?
- Can the protection settings including that of the line be adjusted online?

Technical explanation of the proposed approach

- Comprehensive technical specifications and manufacturing of a 60 MVA transmission class flexible LPT
- Developed an augmented transformer protection relay (e.g. GE Multilin T60)
- Equip transformer with new protection relay and deploy at a utility site for performance validation
- Evaluate potential of nano dielectric fluids for an optimized design of flexible LPT
- Develop gas monitoring systems for improved monitoring of the prototype during field validation

Project schedule, deliverables, and current status

- $2.97MM - project not started yet.
- Anticipated start date 10/1/2019

Milestone	Description	Planned completion
Specifications of the flexible transformer completed	All inputs to start the design are available	Q1
Augmented transformer protection relay developed and tested	The GE Multilin relay used to develop protection of the prototyped transformer with online adjustable impedance is successfully tested in the lab	Q4
Specified transformer manufactured, tested and shipped	The manufactured transformer is successfully tested in the factory according to ANSI/IEEE C57.12.90	Q5
Enhanced flexible LPT designed	Optimized design of the flexible LPT using the characteristic of nano-dielectric fluid is completed	Q6
Designed transformer tested and validated in the field	The prototype is successfully installed, energized and tested for up to six months of operation in the utility substation	Q8

Anticipated challenges and risk mitigation strategies

Risk	Potential impact	Mitigation strategy
Inability to find a utility partner for the field demonstration.	The prototype will be tested a lab and not expose to “real life” stress to prove the validity of the design	Talk with multiple utilities for proposal of scope aligned with their available host station. Leverage Prolec GE customers relationship to work with utilities whom it is already an approved provider. Discuss with DOE for a workable asset ownership at project end.
Flexible transformer size/footprint surpasses conventional transformer size >20%. Online impedance changer increases size >10%.	Bigger size transformer will be hard to fit in existing substations. May require special pads/special bushings.	Design optimization stage: Ensure it is within 10% window. Deploy special mechanical design methods/processes to reduce transformer tank size. Leverage load tap changer optimization methods to the design of impedance tap changer.
Short circuit impedance range is narrow or outside of the range specified	Short circuit impedance is key to LPT and missing the target will impact the flexibility feature of the designed prototype.	Verify through Finite Element Analysis (FEA) that short circuit impedance in the final design is within range. Perform sensitivity analysis on key parameters affecting on the short circuit impedance and keep them within specified range.
Transformer gets damaged during shipping	Potential loss of the transformer. Inability to test the unit at a utility.	All PGE transformers are equipped with impact recorder, shock absorbers will be added. Select safest route for transportation to the field demonstration utility site. Work only with experienced shipping companies. The prototype will be insured.

Next steps

- Finalize the contract with DOE
- Finalize the contract with the field demonstration partner
- Project kick-off

Broader Impact

- Interacted with multiple utilities for a “Voice of Customers” of the proposed design
- The team is in discussion with potential utility partners for the installation of the prototype in a existing substation (multiple offers). Technology is being disseminated in the industry through that channel.
- National Labs are not excluded from partnership
- Findings that could lead to further innovations
  - Transformer protection and line protection coordination with online change of the LPT short-circuit impedance
  - New insulation oil to further optimize the size of the flexible LPT

Contact Information

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