5/10 MVA HTS Transformer
SPI Project Status

Presented by

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For the DOE Peer Review

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Team:

Waukesha Electric Systems

Superpower, Inc.

Oak Ridge National Laboratory

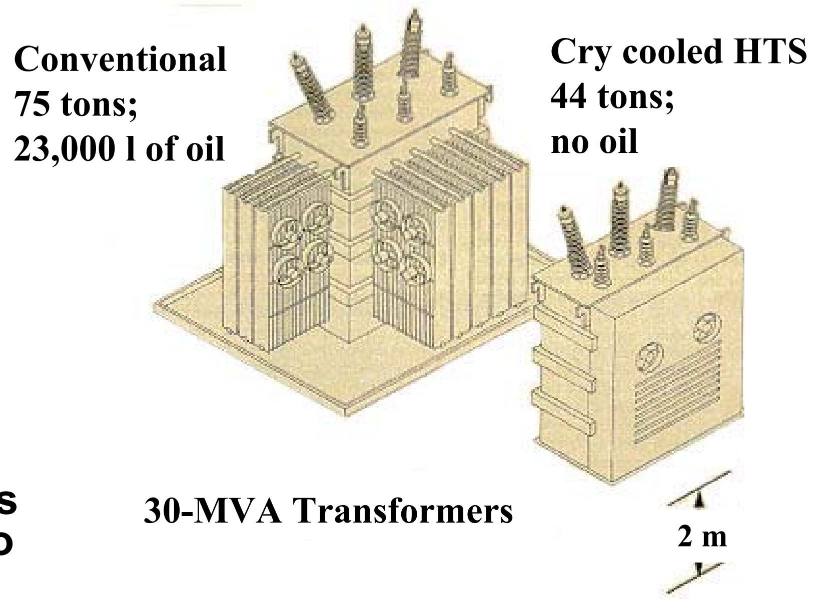
U.S. Department of Energy

Project Purpose

- **To establish the technical and economic feasibility and benefits of HTS Transformers of medium-to-large (>10MVA) ratings.**
  - Phase I—1-MVA demonstration transformer design, fabrication, and testing (complete).
  - Phase II— **SPI**— 30-MVA conceptual design, material & component verification testing, 5/10-MVA Alpha prototype design, construction, test.
  - Phase III— 30-MVA Beta prototype design, construction, test.
- **At present, the project is concluding Phase II.**

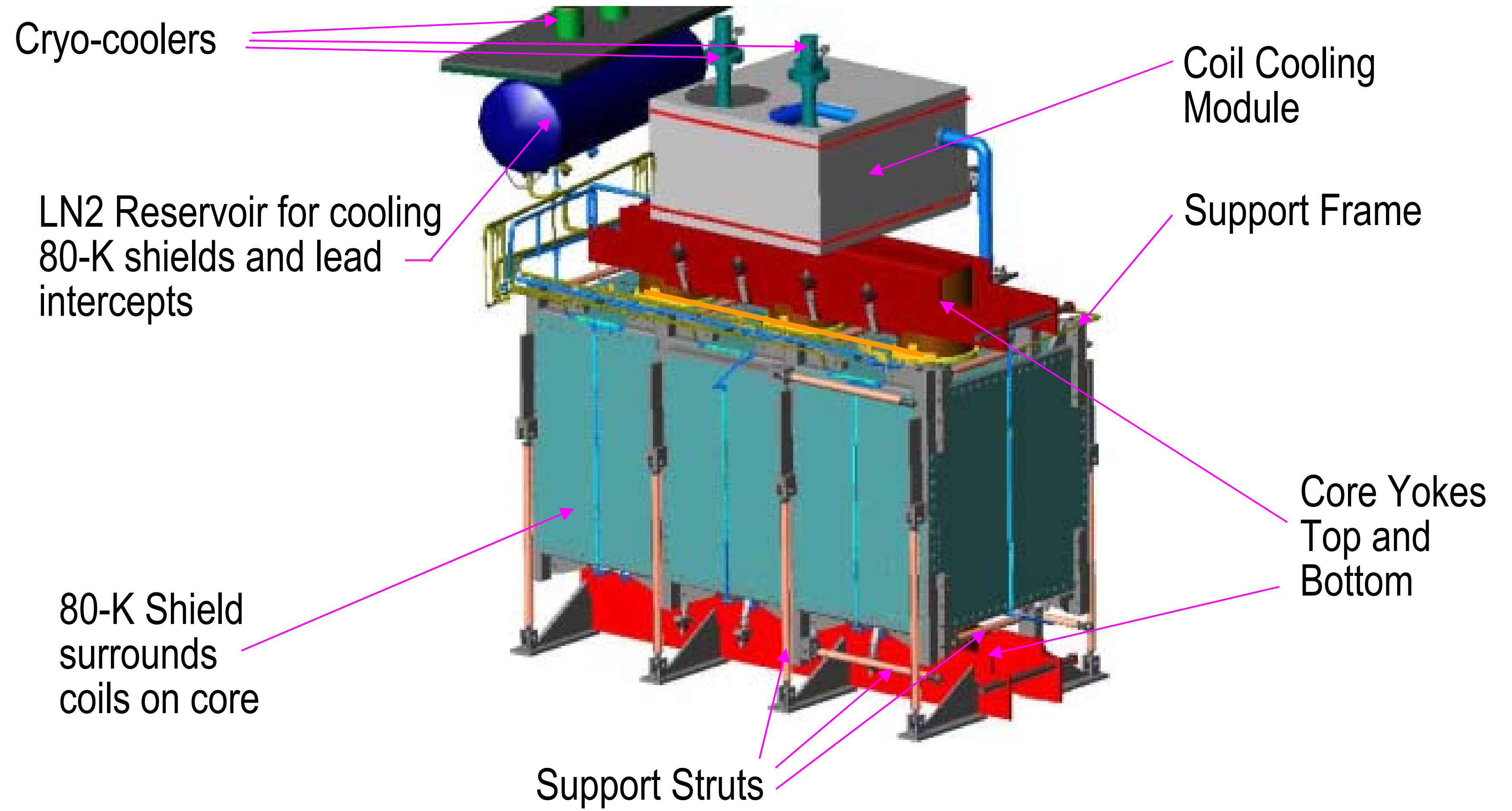
HTS Transformers offer economic, operational, and environmental advantages.

- Higher efficiency.
- 2X rating overload capability without insulation damage or loss of life.
- Lower impedance and better voltage regulation.
- Potential for fault current limiting capability, allowing reduced cost for associated switchgear, breakers, etc.
- Siting advantages, indoors or outdoors and lower environmental hazard due to lack of oil.
- Lighter and more compact than conventional units.
- Greater security– smaller radiators; can interface directly with underground SC cable; no oil to spill or ignite.



30-MVA Transformers

Major Components of 5/10-MVA Design



Summary of Results - 2004

- **What Worked** (Good)
  - Thermal performance and thermal design.
  - He based cryogenic system worked well-unattended.
  - Vacuum performance and tank design.
  - Transportation and Structural design proven ok.
  - Dielectric design / HV connections and bushings.
  - Integration of components form three facilities without problems.

- **What Needed Repair/Upgrades** (Bad)
  - Inadvertent loop/short around C phase limb.
  - LN system leaks. - *More robust system required.*
  - PD inception at very low voltages in all 3 phases. - *Design/Manufacturing issues.*
  - Neutral connection and lead design for single Ø tests - *Undersized.*

- **Issues Yet to be Resolved** (Ugly)
  - Dielectric failure at less than rated voltage.
  - All three phase sets failed in different places.
  - Because of multiple faults – could not test single Ø at full rating.
  - Higher Than Expected Losses (A Phase).

FY 2004 Work

- Repair and test 5/10 MVA unit.
- Install and run unit on utility grid.
- Document lessons learned in the final report.
- Propose a follow-on program to advance dielectric design approach and other open issues.

FY 2004 Performance

- Transformer was repaired, short on "C" phase eliminated; leakage rate reduced. short circuit testing completed; thermal tests finished.
- Installation plans and design completed,
  but dielectric failure prevented installation on grid.
- Testing, assembly and review of issues has generated a list of lessons learned for 30 MVA design.
- Discussions already started, preliminary proposal being prepared.

What's Next?

- **Transformer coils have been removed and returned to SuperPower for further evaluation of problems encountered.**
- **Internal components will be carefully inspected for failure mode.**
- **Design improvements are needed to further streamline manufacturability.**
  - Simplify plumbing to minimize leaks.
  - Improvements to MLI assembly techniques.
  - Simpler cryogenic suspension methods.
  - Develop methods for pre-testing coils at room temperature.
  - Validate HV issues with small single phase models.
- **The team will be meeting to discuss lessons learned and prepare a final report.**
- **The team proposes a follow-on program to study several open issues.**

Follow-on Program Topics

- Cryogenic electrical insulation materials studies for 30-MVA+ design ratings – partial discharge, ac and impulse breakdown strength, aging, tan delta, thermal shock resistance, thermal conductivity, and heat capacity, volume effects, manufacturability, scale-up issues.

- Demonstrate the benefits of incorporating second-generation YBCO materials into the 30-MVA reference design, including ac loss, over current capability, and fault current limiting issues.

- Optimize manufacturability and marketability– design simplicity, reliability, cost, interface to HTS cables, generators, FCL, etc., match to utility requirements.

Our team is committed to the success of HTS Transformers.