



**SuperPower<sub>INC.</sub>**

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OAK RIDGE NATIONAL LABORATORY  
U. S. DEPARTMENT OF ENERGY



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# Development of High Temperature Superconducting Power Transformers

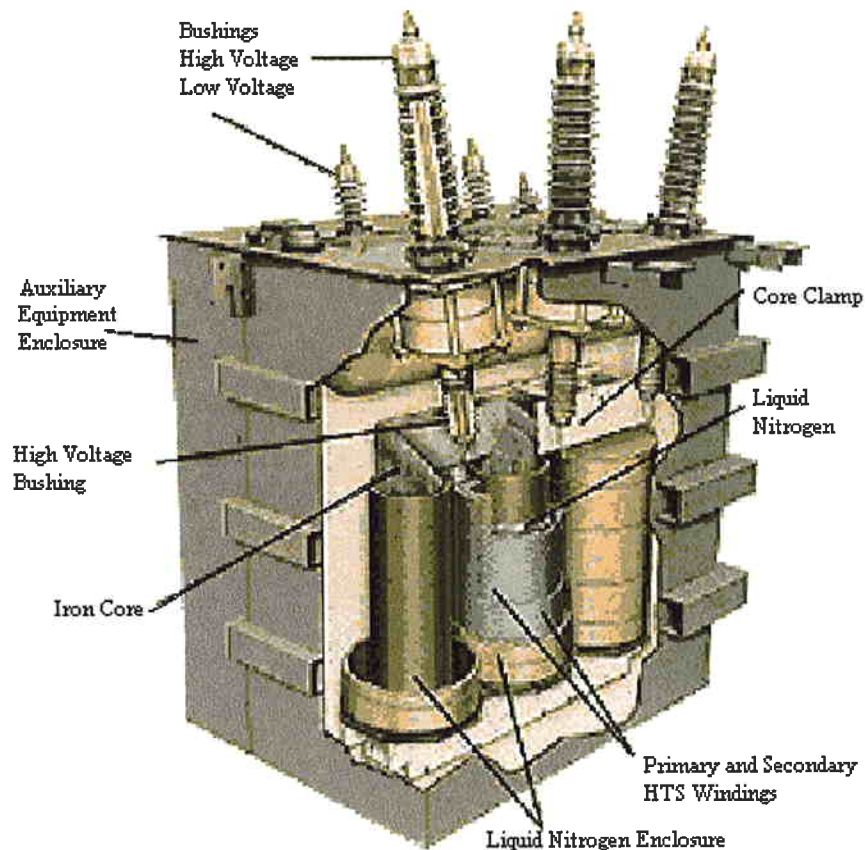
Chandra T. Reis, *IGC-SuperPower, Schenectady, New York*

Sam P. Mehta, *Waukesha Electric Systems, Waukesha, Wisconsin*

Benjamin W. McConnell, *Oak Ridge National Laboratory, Oak Ridge, Tennessee*

Robert H. Jones, *Rochester Gas and Electric Corp., Rochester, New York*

## HTS Transformers offer economic, operational, and environmental advantages.



- **Higher efficiency.**
- **2X rating overload capability without insulation damage.**
- **Lower impedance and better voltage regulation.**
- **Potential for fault current limiting capability.**
  - Reduced cost for associated switchgear, breakers, etc.
- **Lower environmental hazard due to lack of oil.**
- **Lighter and more compact than conventional units.**

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## Higher Efficiency (Lower Operating Losses)

- Core losses
  - Core losses in HTS transformer are comparable to core losses in conventional transformer
- Winding losses
  - No  $I^2R$  losses
  - Load losses generated are on the order of hundreds of Watts at cryogenic temperatures
    - Cryocooler compressor power needed to remove at low temperatures on the order of tens of Watts per Watt of loss
    - Present day compressors run continuously and must be sized for peak load
  - For a 30/60 MVA HTS transformer
    - winding losses are like no-load losses
      - due to power needs of cryocoolers
      - around tens of kilowatts at room temperature vs. one to two hundred kilowatts of load loss for conventional transformer

## Emergency Overload Capability

- Emergency overload capability up to twice the normal rating can be built into the design
  - Very little heating even during this overload condition
    - Remain in the cryogenic condition
    - No thermal degradation of insulation
  - Designed to handle the added overload mechanical forces.
  - Run for extended periods at overload conditions
    - AC losses are proportional to operating current cubed
      - Refrigeration costs are directly proportional to ac losses
      - Operation in this mode tends to be inefficient
      - Operation above the design limit is not practical



## Lower Leakage Reactance

- Lower leakage transformers can be designed because:
  - AC fields are already minimized to reduce ac losses and refrigeration costs
  - Compact windings allowed by high current density
    - May be desirable to incorporate fault current limiting capability so as not to increase system short circuit currents
- Specific benefits to power systems operation are:
  - Improved voltage regulation
  - Reduced impact of faults elsewhere in the system
  - Reduction in required static and dynamic VAR capability
    - Increased reactive power availability from generators
    - Increased availability of real power from existing generators
  - Transformer designs that separate transformer impedance requirements from specific system short circuit current requirements