



## Dr. Troy Beechner

Mission Leader at GE Vernova's Advanced Research Center

*Dr. Troy Beechner*, Mission Leader at GE Vernova's Advanced Research Center, has over twenty-one years of experience in the design and development of power electronic converters for military and commercial applications. He has extensive experience in the design, control, and modeling of motor drives, modular converter systems, and complex energy conversion products ranging in power from tens of kilowatt's to multiple megawatt's. Specific applications have included high-temperature superconducting drives, propulsion drives for small submersibles, solid state transformers, and modular power electronic building blocks, just to name a few. He has served as principal investigator on over 35 government and privately funded R&D and product development efforts, totaling more than \$83M in funding. As a Member of GE Vernova's Advanced Research Center team, he supports the electrification business by driving strategy, development, execution, and deployment of advanced power electronics and energy systems for next-generation energy infrastructure and mission-critical military applications.

# POWER DENSITY, EFFICIENCY, AND THE WRONG QUESTIONS: REFRAMING THE SST VALUE PROPOSITION

Troy Beechner, PhD  
Mission Leader - Electrification  
Advanced Research Center  
Niskayuna, NY

- Who is GE Vernova and the ARC?
- History of SST's at the ARC
- Customer SST specification review
- SSTs: What are the right questions?
- How can AMPED help?

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# WHO IS GE VERNOVA?

# GE Vernova's Portfolio of Businesses:

# ONE-OF-A-KIND



## POWER



- Gas Power**
- Heavy Duty Gas Turbines
  - Aeroderivative Gas Turbines
  - Steam Turbines/Generators



- Steam Power**
- US Nuclear, Global Coal
  - Steam, Generators, Boilers



- Hydro Power**
- Hydro Turbines/Generators
  - Pumped Storage



- Nuclear Power**
- Boiling Water Reactors
  - Fuel
  - Small Modular Reactors

## WIND



- Onshore Wind**
- 2 - 3.5 MW platform
  - 5 - 6 MW platform
  - Services & repowering



- Offshore Wind**
- Haliade-150 (6 MW)
  - Haliade-X (14 MW)



- Wind Turbine Blades**
- ONW blades
  - Haliade X blades

## ELECTRIFICATION



- Grid Solutions**
- Transmission
  - Transformers
  - Grid Automation & Software



- Electrification Software**
- O&G Electrification
  - Naval Electrification
  - Microgrids



- Power Conversion & Storage**
- Inverters
  - Energy storage

+ Prolec

## ACCELERATORS

- Advanced Research**
- Differentiated Technologies
  - External Partnerships

- Consulting Services**
- Power Market Assessments
  - Investment Decision Analysis

- Financial Services**
- 3rd Party Financing Support
  - Direct Financing through Equity

Helping our customers generate

**~30% OF THE WORLD'S ELECTRICITY**

# GE Vernova ... purpose-built to meet global energy demand



The world  
**NEEDS  
MORE  
POWER**  
that's Affordable,  
Clean, Reliable & Secure

## POWER

**7,500 GAS TURBINES  
IN THE FIELD**

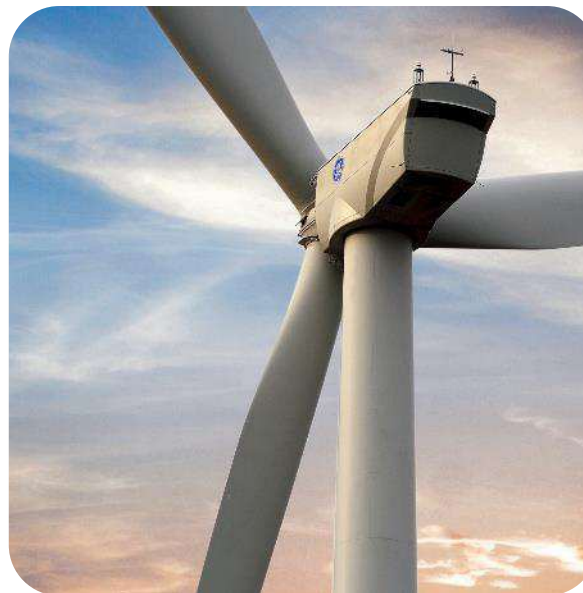
Can advanced manufacturing  
reduce lead-time?



## WIND

**57,000 WIND  
TURBINES IN THE FIELD**

Can increases in quality  
make wind more viable?



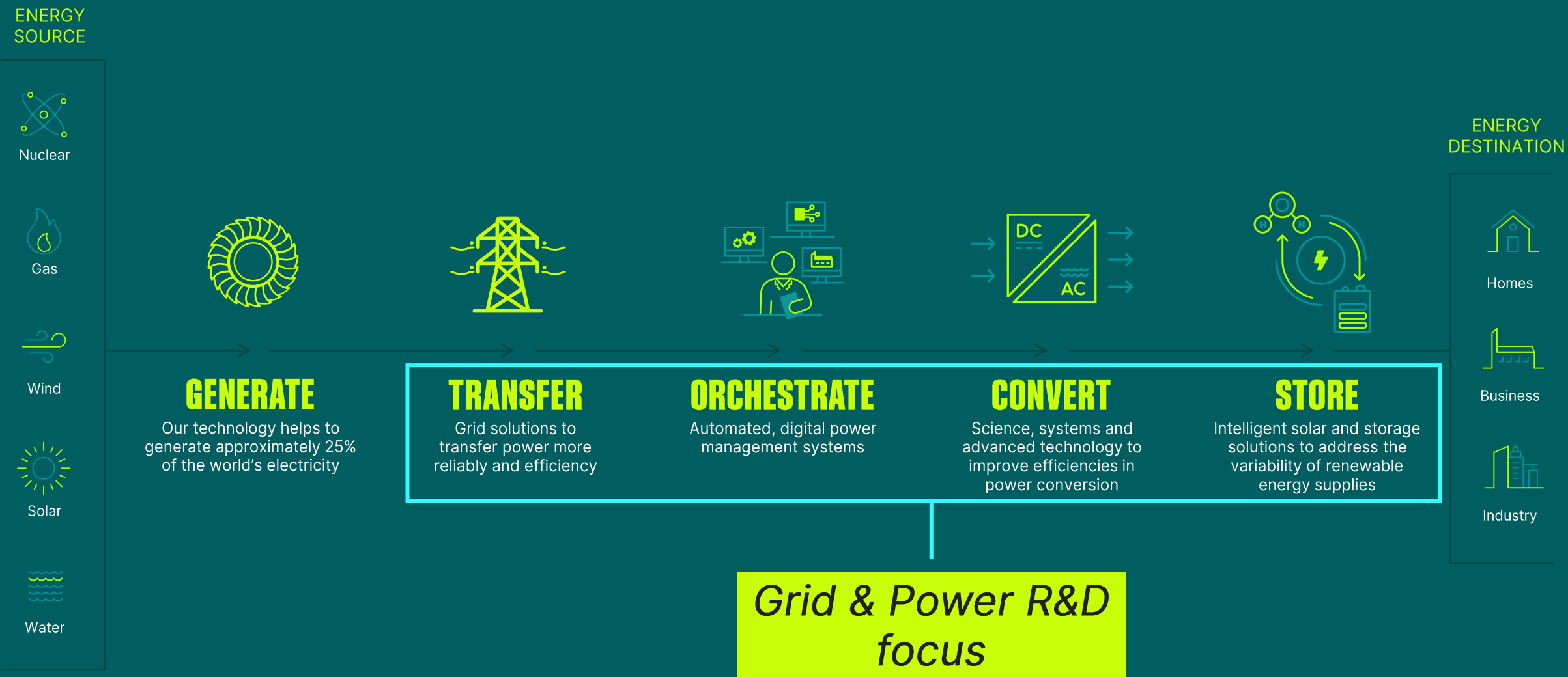
## ELECTRIFICATION

**30% OF THE WORLD'S  
ELECTRONS**

Can we 10x the grid in the  
next 20 years?



# Broadly positioned to deliver grid & power conversion solutions



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# WHAT IS THE ADVANCED RESEARCH CENTER?

# ADVANCED RESEARCH AT A GLANCE

## TALENT & STATS

**~400**

Global Researchers

**~60%**

PhDs

**52**

Technical Capabilities

**420+**

Technology Collaborators

## LOCATIONS



## TECHNOLOGY DISCIPLINES

- Aero & Thermosciences
- AI, Software & Robotics
- Controls & Optimization
- Electrical & Power Systems
- Embedded Systems & Cybersecurity
- Material Chemistry & Physics
- Material Coatings & Modeling
- Mechanical Systems & Design

# ARC HAS MULTIPLE FACILITIES WORLDWIDE

✓ Malta  
Incubate at Pace



✓ Montreal  
Demo & Deploy



❑ Frontier  
Pilot scale & Validate



✓ One Research Circle  
R&D fundamentals



✓ Bangalore  
Integrate with Businesses



TODAY

520 people  
220K sq ft labs



2029

700 people  
400K sq ft labs

World-class facilities enable world-class minds to fulfill their potential

# GE Vernova's Advanced Research Center

## Our **Research to Reality** formula

### CAPABILITIES

-  Electrical & Power Systems
-  Controls & Optimization
-  Embedded Systems & Cyber
-  AI, Robotics & Software
-  Aero & Thermosciences
-  Materials Chemistry & Physics
-  Materials, Coatings & Modeling
-  Mechanical Systems & Design

*400+ researchers, multidisciplinary*



### NETWORKS



#### GOVERNMENT

- National Labs
- DOE agencies
- Military



#### GE VERNOVA BUSINESSES

- Electrification
- Power
- Wind



#### EXTERNAL PARTNERS

- Universities
- Startups
- Industry



### KEY TECH AREAS (subset)



HVDC/MVDC Networks



Solid State Transformers



Solid Oxide (F/E) Cells



Direct Air2X Capture



SMR / Advanced Fuels



Grid Stability Solutions



AI / Robotics / Cyber

*Mission-focused on impact at scale*

# TECHNICAL CAPABILITIES



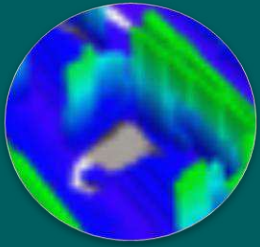
## AI, Robotics & Software

- AI/ML
- COMPUTER VISION
- ROBOTICS
- SOFTWARE ARCHITECTURE



## Electrical & Power Systems

- POWER SYSTEMS
- POWER ELECTRONICS
- ELECTRIC MACHINES
- SENSORS & ACTUATORS



## Controls & Optimization

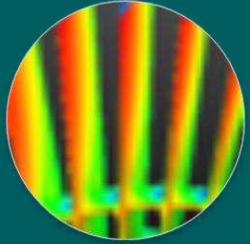
- MODEL-BASED CONTROLS
- REAL TIME OPTIMIZATION
- OPERATIONS RESEARCH
- MODELING & ESTIMATION



## Embedded Systems & Cybersecurity

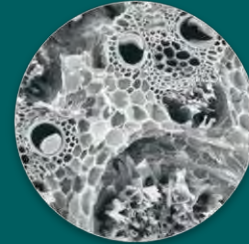
- CYBER-SECURITY
- EMBEDDED SYSTEMS
- INDUSTRIAL COMMUNICATIONS
- EDGE COMPUTING

# TECHNICAL CAPABILITIES



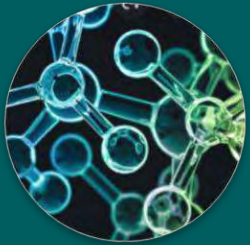
## Aero & Thermosciences

- THERMAL SYSTEMS
- AERODYNAMICS
- COMBUSTION
- HIGH FIDELITY SIMULATION



## Materials, Coatings & Modeling

- HIGH TEMP COATINGS
- CHEMICAL PROCESSING
- MATERIAL INFORMATICS
- MATERIAL CHARACTERIZATION



## Material Chemistry & Physics

- MATERIAL CHARACTERIZATION
- ELECTRO-CHEMISTRY
- MATERIAL INFORMATICS

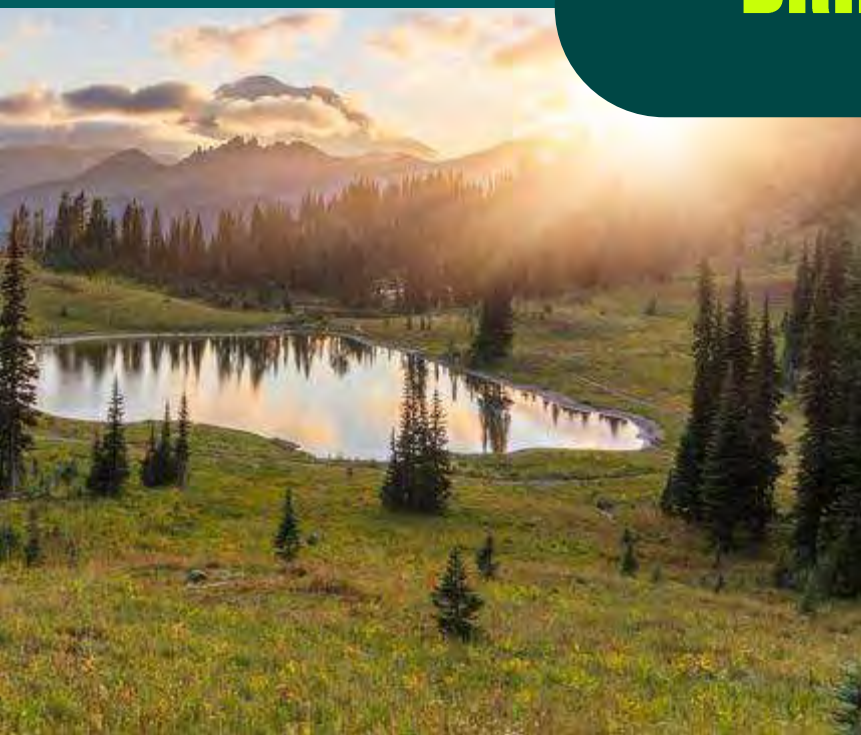


## Mechanical Systems & Design

- ADDITIVE/ADV MFG.
- STRUCTURAL MECHANICS & DYNAMICS
- COMPONENT RELIABILITY
- MECHANICAL DESIGN & TEST
- INSPECTION TECHNOLOGIES

## BRINGING RESEARCH TO REALITY

The Energy of Change



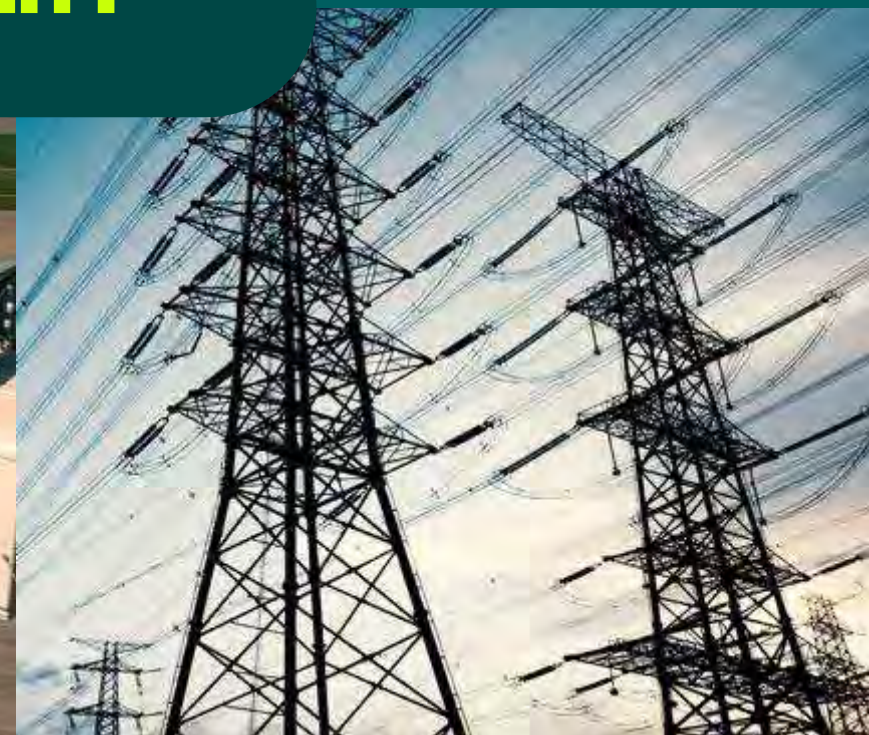
### POWER

Develop and deploy carbon management technologies



### WIND

Grow renewables as fast as possible



### ELECTRIFICATION

Electrify more ... modernize and grow the grid

# ELECTRIFICATION

## Electrify Industries ...Power-2-X



- High power electrification
- Power Stability
- Microgrids / EMS

## Connect & Control Power Systems



- More DC... HV and MV
- Grid Stability & Flexibility
- Heterogeneous Energy Systems

## Build a Flexible, Resilient Grid



- Advanced Transformers/  
Switchgear
- Grid Digitization &  
Orchestration
- Energy security

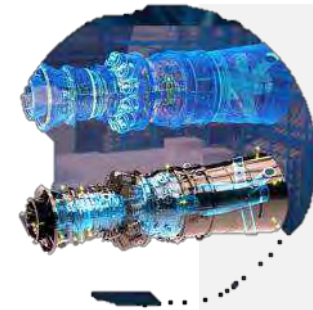
# Accelerators

## Artificial Intelligence Industrial Asset Intelligence & Capability



- Large Language Models for Industrial Asset Analytics
- Accelerating Complex Engineering Design

## Cyber Critical Infrastructure Security



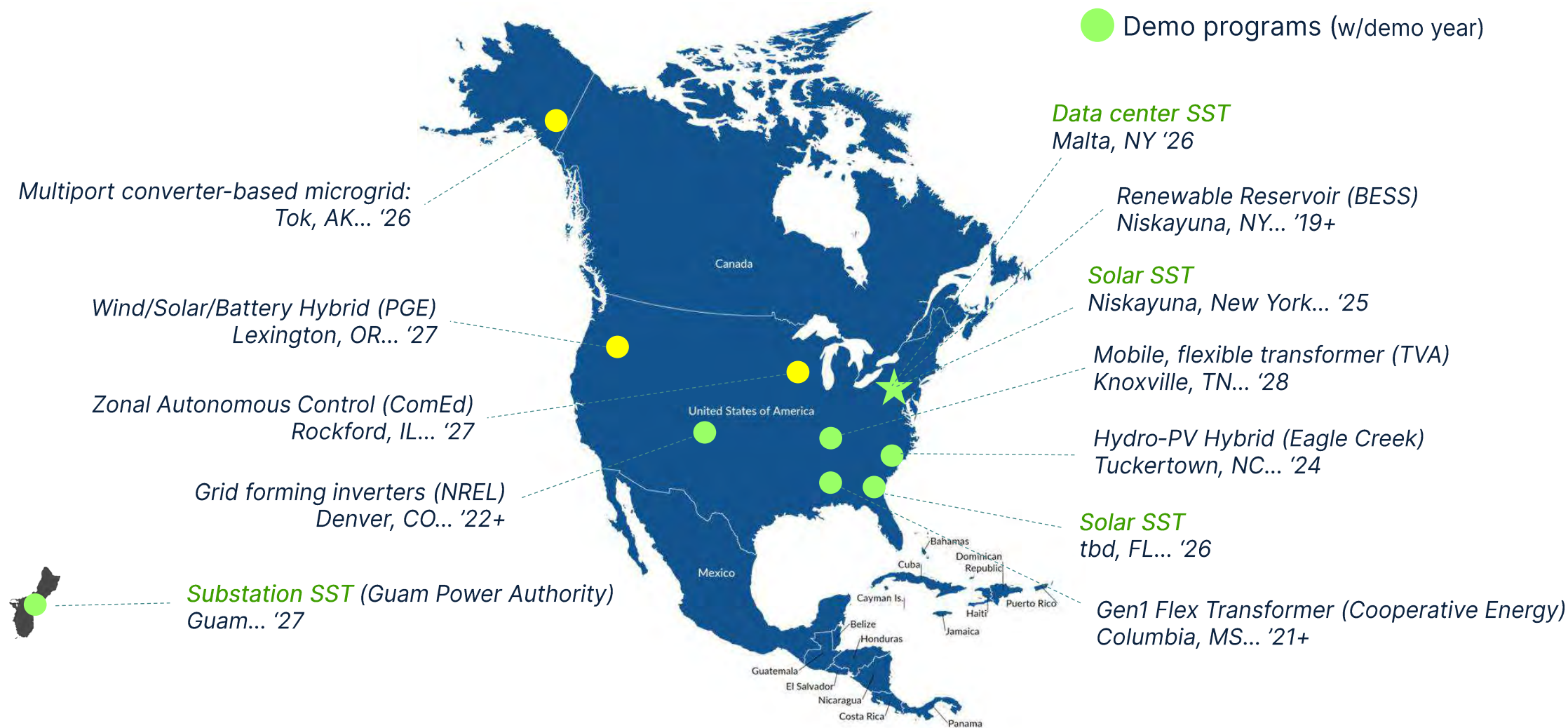
- Critical System Protection
- Models for Cyber Attack Mitigation

## Robotics Augmenting the human workforce



- Safety Assurance: path planning, motion
- Robot Learning: Simulation & Continuous
- Multi-Robot Collaboration

# Technology demonstrators... with external partnerships



Taking Research to Reality ... delivering customer proof points

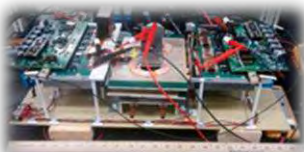
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# SOLID STATE TRANSFORMERS

- ARC SST History – applications focused
- How do we test SST's?
- Reframing the SST value proposition
- What are the wrong, and right, questions?
- How can AMPED help?

# SST Projects at the Advanced Research Center

2018



SST Module 150kVA,  
1-1 kVdc 250 kHz



2009

1 MVA, 13.8 kV/265 Vac,  
20 kHz

Navy

2011

1MW, 4.16kVac/1 kVdc,  
40 kHz

Navy

2020

1MW, 6kVdc/1kVdc,  
200 kHz

Navy

2021

Wind 1MW  
6kVac/0.69 kVac

Wind

2024

Solar 1MW  
20kVdc/1.5kVdc

Solar

Future

Multi-MW  
+34.5kVac/LVDC

Multiple  
Applications

Pioneering SST technology for 15+ years thru' innovative power electronics, magnetics, and insulation

# Malta MVDC Test Facility

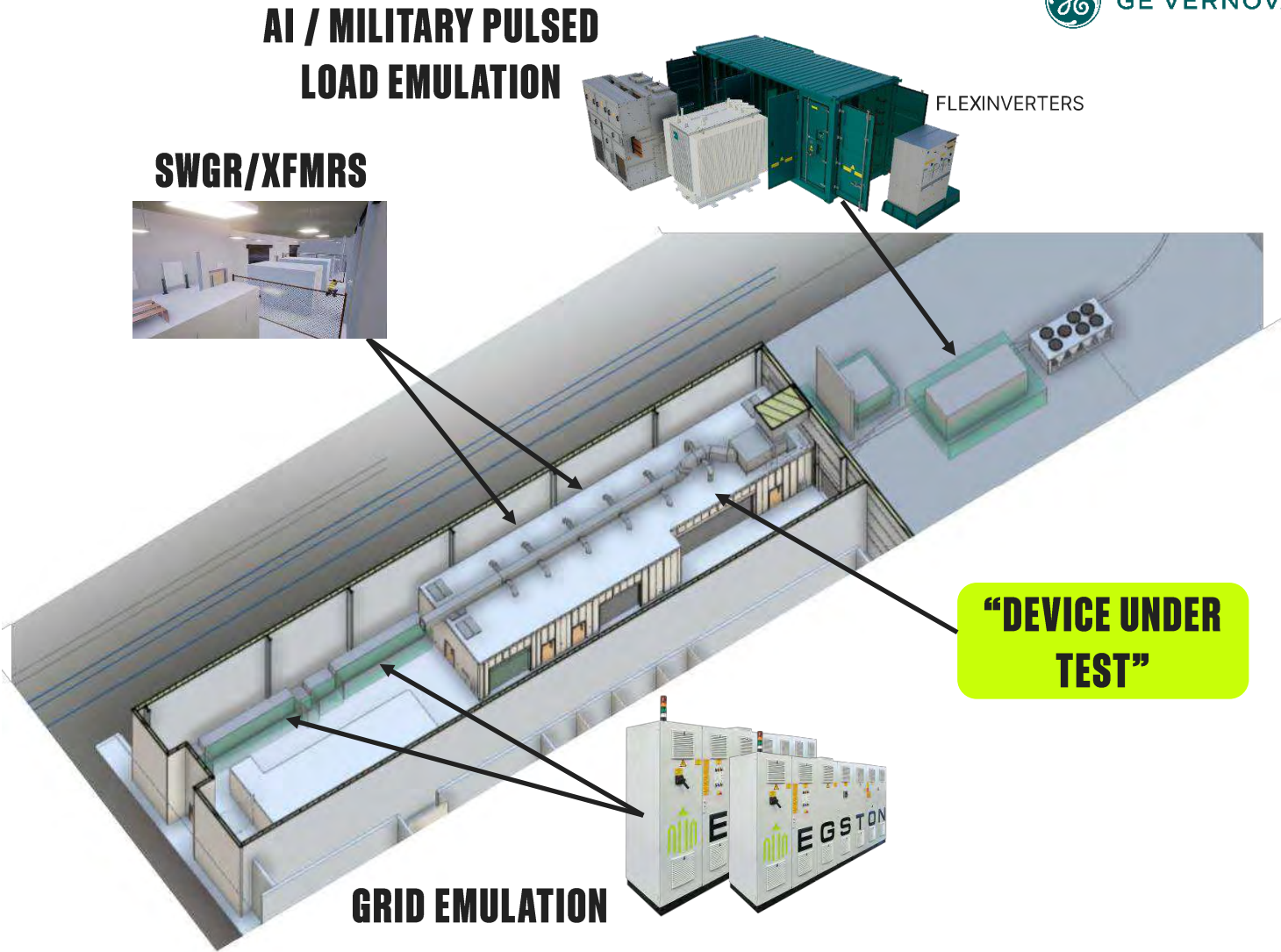
**World Class 5+ MW MVAC/MVDC Test Facility**

- Multiple Power-Hardware-In-the-Loop amplifiers
  - Enabling grid, AI, and pulse load emulation
- Pump back testing up to +5MW, +34.5kVac, +2kVdc
- Multiple variable AC and DC power supplies

| Grid Emulation | Datacenter Emulation |        | Up to+ 5 MVA<br>power re-circ |
|----------------|----------------------|--------|-------------------------------|
| 480V           | 4160V                | 34.5kV |                               |
| 2kVdc          | 6900V                | 13.8kV |                               |

High BW XFMRs

*Future-Proof lab for testing SST's and beyond*



Ability to Test AI / Military Pulsed Load Profiles at Scale

# Reframing the SST Value Proposition

“...Large Scale Deployment of SSTs is Nowhere to be seen? What happened? [1]

## SST Value Proposition?

- ❖ Always cited: Efficiency & Power Density
- ❖ Others: Cost, feature set, weight, etc.

## High TRL demonstrators

- ❖ EV Fast Charging [2], Traction [3], Military, others

## What's Missing?

- ❖ Demand doesn't meet supply
- ❖ New SST functions not vital, mature tech simpler
- ❖ Still have technical gaps

## What do we do?

- ❖ Application specific techno-economic analysis
- ❖ Identify new critical applications

## What's happened over the last 3 years?

- ✓ AI is infiltrating every application space
- ✓ Datacenter boom is everywhere
- ✓ Funding for industrialized SSTs is skyrocketing
  - ❖ Small company acquisitions...
  - ❖ Startups w/ significant VC funding...

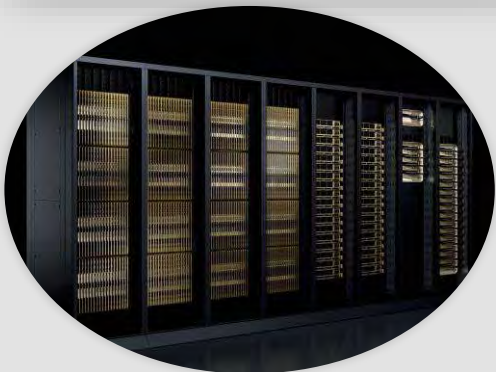


**Let's re-visit the deployment question, answer “What's missing”**

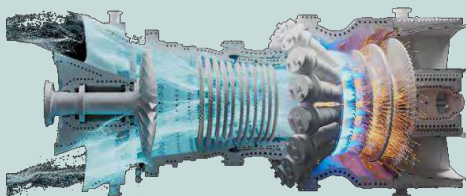
Lets take a closer look at two applications: Datacenters and Naval Shipboard

# Starting to Answer “What’s Missing”

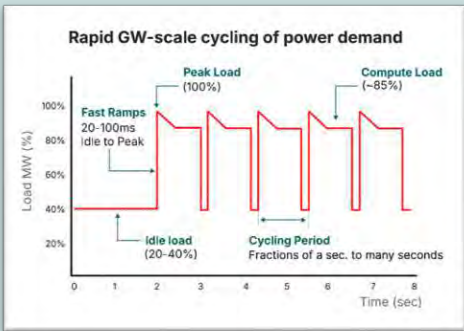
## DATACENTERS



## COMMONALITIES



## GAS TURBINE INTERCONNECTION



## PULSED / STOCHASTIC LOADS

## NAVAL SHIPBOARD



Two applications... common underlying electrical challenges... what about gaps?

# Next-Generation Solid-State Transformers for Powering Artificial Intelligence Data Centers

## A Survey of Emerging Topologies

June 2026 – Industrial Electronics Magazine [6]

*"... today's industrial fully modular demonstrators show a limited power density of roughly 0.2 MW/m<sup>3</sup>, which is insufficient for supporting the targeted high compute densities."*

## What is focus of past SST efforts?



- ❖ Excellent paper from IEEE SST Task Force [8]
- ❖ Finding: Past work focus:
  - Efficiency
  - Topologies
  - Power density

## Questions

1. Are demonstrator power densities insufficient for datacenter applications?
2. Should SST researchers and developers still prioritize power density and efficiency?
3. Do we need 1 MW/m<sup>3</sup> and >99% efficiency?

## What do customer specifications actually say?

# Datacenter Application – Customer Specification

## Datacenter Customer Requirements [4]



- ...reduce bespoke designs...
- ... SKU A – 13.8 kV... SKU B – 34.5 kV...
- ...improve supply chain scalability...
- ...predictable reliability and availability metrics...
- ...option 1: Indoor... Option 2: Outdoor...
- ...specific dimensions for height/depth
- ...5 MW, 0.14 – 0.27 MW/m<sup>3</sup>, >=98% efficiency

Authors  
❖ NVidia  
❖ Google  
❖ Microsoft

## Customer Priorities

- ✓ Packaging commonality: SKU's / Vendors
- ✓ Compliance with ERCOT LLI Framework
- ✓ 15 yr design life
- ✓ Supply chain, reliability, availability
- ❖ PD and Efficiency already met

## SST Value Proposition

- ✓ TCO reduction
- ✓ Footprint reduction
- ✓ Weight reduction

## Req. Criticality Assessment

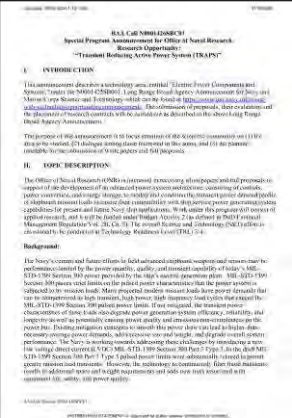
| Requirement     | OCP Specification |                  |
|-----------------|-------------------|------------------|
| Efficiency      |                   | ✓ >98.5%         |
| Power Density   |                   | ✓ OCP Spec       |
| Cost - TCO      |                   | TBD              |
| Bi-Directional  |                   | Vary by vendor   |
| Availability    |                   | 99.99% min.      |
| Reliability     |                   | N+1 min.         |
| Maintainability |                   | Strict MTTR      |
| Dimensional     |                   | Constrained      |
| Weight          |                   | Open new layouts |
| Environment     |                   | Inside / outside |
| Energy Storage  | Yes               | AI load profile  |
| Power Level     | 5 MW+             | Spec. driven     |
| Black Start     | No                | Vary by vendor   |
| Interface       | MVAC/DC           | 34.5 kV target   |
| Req. Body       | OCP, IEEE         | In Development   |

Req. Criticality High Med. Low

Customer are telling us power density and efficiency at NOT the bottleneck.

# Naval Shipboard Application – Customer Specification

## Navy Customer Requirements [5]



Author  
❖ ONR

...minimize size and weight without sacrificing power quality performance ,availability, or equipment life.

...7 ft. max height requirement

...no clear min efficiency given, **higher better**

...mil-std-1399 section 300 compliant profile

...650kW/2.6MW.... Scaling to 5 MW

...fault management, load shedding...

## Customer Priorities

- ✓ Must fit into ship arrangements
- ✓ **Survivability**
- ✓ Power quality
- ✓ 20+ yr design life
- ✓ **US Supply chain**, reliability, availability
- ❖ Spec references AI load profiles

## SST Value Proposition

- ✓ Energy Storage Integration
- ✓ Footprint reduction
- ✓ Weight reduction
- ✓ Increased survivability, redundancy
- ❖ What is the warfighter benefit?

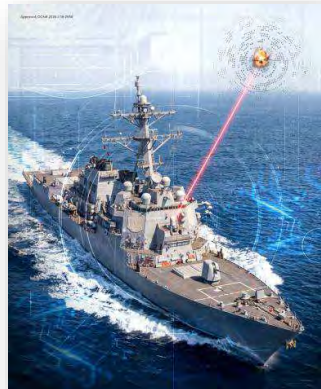
### Req. Criticality Assessment

| Requirement     | Navy Specification                                                                  |                             |
|-----------------|-------------------------------------------------------------------------------------|-----------------------------|
| Efficiency      |  | >98% typical                |
| Power Density   |  | Maximize                    |
| Cost - TCO      |  | Low volume, niche           |
| Bi-Directional  |  | Vary by spec.               |
| Availability    |  | High                        |
| Reliability     |  | 40+yr Life                  |
| Maintainability |  | Strict MTTR, liftable       |
| Dimensional     |  | Legacy HW fit               |
| Weight          |  | Minimize                    |
| Environment     |  | Shipboard / Shock           |
| Energy Storage  | Yes                                                                                 | Pulsed load                 |
| Power Level     | Multi-MW                                                                            | Up to 5 MW                  |
| Black Start     | Yes                                                                                 | Conops driven               |
| Interface       | LVAC/MVAC/DC                                                                        | Vary by Ship                |
| Req. Body       | Navy/Shipyard                                                                       | Mature, <b>but outdated</b> |

Req. Criticality  High  Med.  Low

ONR is painting a similar picture as the OCP specification

# Customer Specification & Application Summary



Datacenter SST

Naval Shipboard SST

|                               | Google, Nvidia, Microsoft<br>OCP                              | ONR<br>IEEE, ABS, NAVSEA, others...             |
|-------------------------------|---------------------------------------------------------------|-------------------------------------------------|
| Who wrote the requirements?   |                                                               |                                                 |
| Demand driver                 | AI training                                                   | Directed Energy, Railgun,...                    |
| Is power density limiting?    | No... OCP spec says we are already there...                   | No... but must fit ship arrangement             |
| Is efficiency limiting?       | No... same answer...                                          | No... but higher is better                      |
| What "reliable" means:        | 99.999% availability<br>N+1 redundancy                        | Survive battle damage,<br>reconfigure around it |
| Impact of getting it wrong... | Lost compute, lost revenue<br>Distribution grid events/faults | Loss of capability<br>Warfighter at risk        |

## Req. Criticality Assessment

| Requirement     | OCP Spec. | Navy Spec.   |
|-----------------|-----------|--------------|
| Efficiency      | Yellow    | Yellow       |
| Power Density   | Yellow    | Yellow       |
| Cost - TCO      | Red       | Yellow       |
| Bi-Directional  | Green     | Yellow       |
| Availability    | Red       | Red          |
| Reliability     | Yellow    | Red          |
| Maintainability | Red       | Red          |
| Dimensional     | Red       | Red          |
| Weight          | Yellow    | Red          |
| Environment     | Green     | Red          |
| Energy Storage  | Yes       | Yes          |
| Power Level     | 5 MW+     | Multi-MW     |
| Black Start     | No        | Yes          |
| Interface       | MVAC/DC   | LVAC/MVAC/DC |
| Req. Body       | OCP       | Navy/ONR     |

Req. Criticality ● High ● Med. ● Low

Two very different SST designs... same answer on power density and efficiency

# The Wrong, and Right, Questions

**Power Density, Efficiency, and the Wrong questions:  
Reframing the SST value proposition**

|                      | Wrong Question                                                                                                                                                     | Right Question                                                                                                                                                                                                |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Density & Efficiency | How small / efficient can we make it?                                                                                                                              | What does the application require?                                                                                                                                                                            |
| Weight               | How light can we make it?                                                                                                                                          | How light can we make it such that it changes installation location, costs, arrangements?                                                                                                                     |
| Cost                 | How does the cost of an SST compare to a LF XFMR?                                                                                                                  | How does the Total Cost of Ownership for an SST based power system compare against the legacy solution/architecture?                                                                                          |
| Technical Gaps       | Remaining: <ul style="list-style-type: none"><li>• MV Insulation</li><li>• MVMF XFMR</li><li>• PD &amp; Insulation Coordination</li><li>• Cyber Security</li></ul> | Re-frame to: <ul style="list-style-type: none"><li>• Lifetime, Reliability, Availability</li><li>• MTTR, MTBF, MTTF</li><li>• Maintainability</li><li>• Meeting application specific specifications</li></ul> |

The right questions are linked to the application.... and that’s the point

## Large Scale Deployment of SSTs is Nowhere to be seen? What happened?

Possible Grid Interactions... documented cases of large load transient challenges

Absence of standards/qualifications... what safety agency will qualify hardware? What specs apply?

Supply chain development... lack of 2<sup>nd</sup> source for critical parts

Lack of field service personnel... requires new model vs historical power systems

Customer advocate left the company... no one driving the changes

Many more reasons...

## Keep in Mind

- ✓ Customers don't buy cool technology, they buy **capability, reliability, reduced down-time, cost savings**
- ✓ SSTs are NOT stand-alone products... **System solutions required**
- ✓ R&D community agrees on SST challenges:
  - But should be linked to **customer requirements**.

## How do we move forward?

- ✓ Prioritize proof points – **get to field pilots ASAP**
- ✓ Understand customer priorities... **May not be what you think.**
- ✓ Articulate value proposition.... **How will you stand out common footprint required?**
- ❖ Dedicated multidisciplinary team with clear vision and engaged customer

These are the types of challenges.... and questions... we attack at the ARC.

# How can AMPED Help?



## Re-Frame SST Problem Statements

- FOCUS ON APPLICATIONS / CUSTOMER NEEDS...
- POWER DENSITY ISN'T ALWAYS KING
- RECENT PUBLICATIONS MOVING THIS WAY.... [7][8]

## Focused R&D

- OPPORTUNITIES TO DRAMATICALLY IMPROVE COST, AVAILABILITY, RELIABILITY:
- NOVEL MATERIALS & INSULATION SYSTEMS
  - APPLICATION SPECIFIC PACKAGING CONCEPTS
  - **Advanced magnetics sit at the intersection of materials, insulation systems, and thermal management**

## Think Beyond SST HW

- ALWAYS TCO
- NEED HOLISTIC SYSTEM/FACILITY END-TO-END SOLUTION
- ASK WHAT ARCHITECTURES BEST EXPLOIT BENEFITS?

## Workforce Development

- ENGINEER TRAINING
- PROCESS DEVELOPMENT
- STANDARDS DEVELOPMENT (EX. P3105)
- WE NEED SYSTEMS ENGINEERS

AMPED is uniquely positioned to make significant impacts in SST deployment



GE VERNOVA

# References

- [1] PCIM Paper - Solid State Transformers: How far have we come?
- [2] Delta SST
- [3] ABB SST
- [4] OCP Spec
- [5] TRAPS Solicitation
- [6] AI Datacenter Paper - Kolar
- [7] Nature SST Paper
- [8] F. Wald et al., "Applications and Services of Solid-State Transformers in Active Distribution Networks—A Critical Review," in IEEE Transactions on Smart Grid, vol. 16, no. 5, pp. 3615-3637, Sept. 2025, doi: 10.1109/TSG.2025.3574007