Request for Information DE-FOA-0003581 on Active Substations with Flexible Large Power Transformers

INTRODUCTION:

The purpose of this Request for Information (RFI) is to solicit input for a potential future ARPA-E program to support research and development (R&D) projects focused on technologies to improve the resilience, reliability, and security of the electric grid through innovations in substations. The goal of this potential R&D effort is to support the development of technologies that fast-track the manufacturing of large power transformers (LPT) and other substation components, while increasing their modularity, performance, functionality, and power density. ARPA-E is seeking information at this time regarding transformative, scalable, and rapidly deployable technologies that could:

- Reduce the cost, lead time, and size of substation components;
- Reduce the requirement for critical materials in substations and the grid;
- Improve the power capacity of existing infrastructure;
- Improve the stability and resilience of the grid; and
- Enhance protection of substation assets from cybersecurity threats.

ARPA-E is requesting information about substation-related problems and the technological innovations that could address those problems. While significant and wide-ranging opportunities for improvement exist, ARPA-E programs seek to identify specific priority areas for technology development to make maximum impact. Therefore, this RFI solicits input from a wide range of disciplines and stakeholders such as power systems and power electronics experts, transformer manufacturers, substation developers, magnetic material scientists, energy storage experts, and other related communities to explore innovative and disruptive ideas related to active substations. ARPA-E is interested in input related to substation planning, design and commissioning, magnetic and copper material usage, and system resilience. ARPA-E is also interested in large power transformer-related challenges such as supply chains, manufacturing, and transport.

It is expected that respondents will inform the agency of key components or system-level areas where accelerated advancements are needed. Example component areas of interest include, but are not limited to, magnetic and dielectric materials, bushings, electric field management, magnetic flux materials, thermal designs, and winding insulation. Example system-level solutions of interest include, but are not limited to, flexible (hybrid) power transformers with modular power converters, solid-state transformers for high-voltage applications, hybrid transformers with integrated energy storage, modular transformer designs with basic transformer blocks, and mobile substations for capacity and resilience management.

AREAS NOT OF INTEREST FOR RESPONSES TO THIS RFI:

- Non-substation and non-large power transformer-related areas;
- Low-level control (modulation) of power electronics converters; and
- Power semiconductors design, development and manufacturing

RFI GUIDELINES:

CAREFULLY REVIEW ALL RFI GUIDELINES BELOW.

Note that the information you provide will be used by ARPA-E solely for potential program planning, without attribution. **THIS IS A REQUEST FOR INFORMATION ONLY. THIS RFI DOES NOT CONSTITUTE A FUNDING OPPORTUNITY. NO FUNDING OPPORTUNITY EXISTS AT THIS TIME.**

The purpose of this RFI is solely to solicit input for ARPA-E's consideration to inform the possible formulation of future research programs. ARPA-E will not provide funding or compensation for any information submitted in response to this RFI, and ARPA-E may use information submitted to this RFI without any attribution to the source. This RFI provides the broad research community with an opportunity to contribute views and opinions.

No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E may contact respondents to request clarification or seek additional information relevant to this RFI. All responses provided will be considered, but ARPA-E will not respond to individual submissions or publicly release a compendium of responses. **Respondents shall not include any information in the response to this RFI that could be considered proprietary or confidential**.

Responses to this RFI should be submitted in PDF format to the email address **ARPA-E-RFI@hq.doe.gov** by **5:00 PM Eastern Time on Monday, September 22, 2025.** Emails should conform to the following guidelines:

- Insert "<your organization name> - Response to Active Substations with Flexible Large Power Transformers" in the email subject line.
- In the body of your email, include your name, title, organization, type of organization (e.g., university, non-governmental organization, small business, large business, federally funded research and development center [FFRDC], government-owned/government-operated [GOGO]), email address, telephone number, and area(s) of expertise.
- Responses to this RFI are limited to no more than 10 pages in length (12-point font size).

RFI QUESTIONS:

The questions posed in this section are organized into several different groups. Respondents may provide responses and information about any of the following questions. **ARPA-E does not expect any one respondent to answer all, or even many, of the questions in this RFI.** In your response, indicate the question number(s) you are responding to (e.g., Response to RFI Questions 8.e,f, and k). Appropriate citations are highly encouraged. Respondents are also welcome to address other relevant avenues or technologies that are not outlined below, except for those that fall under the "Areas Not of Interest for Responses to this RFI" described above.

1. For each of the following items, provide your input on whether it should be a focus of a potential new program on active substations with flexible large power transformers. Answers should begin with 'Yes' or 'No', followed by elaboration.

    a) Transmission to sub-transmission voltage levels (i.e., 345 kilovolts [kV] to 110 kV)
    b) Sub-transmission to medium voltage levels (i.e., 110 kV to 24 kV)
    c) Development of modular active and passive substations for mass production
    d) Compact active substations utilizing medium- and high-voltage solid-state transformers
    e) Improved grid support and stability with hybrid active substations that comprise power electronics-enhanced transformers
    f) Materials development to improve or replace copper, grain-oriented electrical steel, or insulation in large power transformers

g) Improving passive transformers (i.e., additive manufacturing; better magnetic, dielectric, and/or insulation materials)
h) Hybrid (power electronics-enhanced) transformers for partial voltage control and full current control
i) Development of modular active and passive substations for mass production
j) Solid-state transformers for full flexibility and control
k) Modular transformer solutions (for either passive, hybrid, or solid-state transformers)
l) Substation energy storage technology
m) What other substation components, design packaging, or materials should a potential new program focus on instead of those mentioned above?

2. How much could substation engineering, procurement, and construction (EPC) time and cost be reduced with new technologies to make an impact (e.g., % or X-fold)?

3. How much could active substations enable increased grid utilization capacity over state-of-the-art?

4. How much should grid and substation losses be reduced?

5. Should a potential new program focus on the integration of energy storage and substations for improved grid resilience? (If yes, please specify how many hours of energy storage support – e.g., more than 4 hours of energy storage support at 80% capacity.)

6. How important are mobile active substations that can fit in a shipping container?

7. **General substation technologies**:

a) What are the main issues related to substation components that utilities encounter?
b) What should substations of the future look like?
c) Could substations be eliminated? If yes, how?
d) Could the function(s) of substations be distributed rather than centralized?
e) How could critical materials (copper, grain-oriented electrical steel, etc.) usage be reduced in substations?
f) What could substations do in the future that they cannot do today?
g) What are specific concerns around substations related to fast electrification in the U.S.?
h) Why are fault currents increasing in some areas? Is this a problem that should be addressed?
i) What opportunities exist for retrofitting existing substations/substation components?
j) How could additive manufacturing play a role in substations?
k) Are there other manufacturing or assembly logistics related to substations that are highly problematic?
l) Could “substation in a box” be implemented in a shipping container? What issues do you see with this idea?
m) Is there a practical lower limit on the size of a substation?
n) What opportunities are there to streamline the EPC time for substations?
o) What do utilities need to see to get past the pilot stage for new substation components?
p) Are there any emerging technologies, ideas, or issues related to substations you think ARPA-E should take a closer look at?
q) Could you provide any contacts you recommend we reach out to in this area (name, organization, email address)?

8. **Large power transformers**:

a) What are the technical reasons large power transformer designs are often bespoke?
b) Why are transformer designs not more standardized?

c) What are the key performance features of traditional 50/60 Hertz (Hz) LPTs that must be preserved if replacing them with new technology?
d) What key features should future transformers have?
e) What role(s) can hybrid transformers (traditional transformers with additional functionality) play?
f) What are some key technology characteristics for hybrid transformers?
g) How much (in terms of megawatts and megawatt-hours) energy storage would be useful in a high-voltage (defined as greater than 69 kilovolts alternating current [kVac]) substation to help with transmission constraints?
h) What are the roadblocks to adopting high-voltage (>69 kVac) solid-state transformers (SSTs) in substations?
i) What are some key technology characteristics of high-voltage SSTs that should be addressed if used in substations (at >69 kVac)?
j) Why are traditional 60 Hz transformers not modularized today?
k) What are the key challenges and technologies around modular transformers that should be considered?
l) Should modular transformers be assembled onsite or in the factory? Why or why not?

9. Other relevant substation components:

a) How should fault coordination between substations change?
b) What should the ideal short-circuit fault levels be in a future substation?
c) What are the challenges of gas-insulated substations besides cost?
d) What specific energy storage technology would be useful if integrated in substations?
e) What are the challenges to adopting superconducting components in substations?
f) How could the cost of reactive power compensation be brought down?
g) How could the size of reactive power compensation be reduced?
h) How could dynamic frequency and voltage support in substations have a larger impact?
i) What other components in a substation or operational scenarios are critical to consider (e.g., bushings, voltage and current transformers, insulation, tap changers, flexible AC transmission system devices, electromagnetic pulse, increasing fault currents)? Why?
j) What components in a substation could be eliminated or combined?
k) What opportunities exist for material innovations in substations?
l) What standards or references should be considered in developing a program related to substation components?