U.S. DEPARTMENT OF ENERGY

Strategic Transformer Reserve

Report to Congress
March 2017

United States Department of Energy
Washington, DC 20585

Page left intentionally blank

Message from the Acting Assistant Secretary

This report responds to legislative language set forth in Section 61004 of the Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94), 129 Stat. 1780,wherein it is stated:

> ... *"(1) PLAN.—Not later than 1 year after the date of enactment of this Act, the Secretary, acting through the Office of Electricity Delivery and Energy Reliability, shall, in consultation with the Federal Energy Regulatory Commission, the Electricity Sub-sector Coordinating Council, the Electric Reliability Organization, and owners and operators of critical electric infrastructure and defense and military installations, prepare and submit to Congress a plan to establish a Strategic Transformer Reserve for the storage, in strategically located facilities, of spare large power transformers and emergency mobile substations in sufficient numbers to temporarily replace critically damaged large power transformers and substations that are critical electric infrastructure or serve defense and military installations."*

This Report to Congress describes the national importance of a strategic transformer reserve, the results of a technical analysis conducted by Oak Ridge National Laboratory (ORNL), and current efforts underway by both industry and the government to mitigate potential threats to the U.S. bulk power grid created by the vulnerability of large power transformers. Based on the technical analysis and an examination of current efforts underway by industry and Government entities, the Department of Energy (DOE) evaluated options for establishing a strategic transformer reserve and recommends encouraging and supporting an industry-based option driven by voluntary industry actions and North American Electric Reliability Corporation's Reliability Standard CIP-014-2 requirements, which were approved by the Federal Energy Regulatory Commission (FERC). DOE further recommends that one year from the date of this report, it work with FERC and electricity industry partners to re-assess whether sufficient progress that has been made through this approach to warrant continuation or alternative actions by Government.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- The Honorable Rodney P. Frelinghuysen
  Chairman, House Committee on Appropriations

- The Honorable Nita M. Lowey
  Ranking Member, House Committee on Appropriations

- The Honorable Mike Simpson
  Chairman, Energy and Water Development Subcommittee
  House Committee on Appropriations

- The Honorable Marcy Kaptur
  Ranking Member, Energy and Water Development Subcommittee
  House Committee on Appropriations
- The Honorable Thad Cochran
  Chairman, Senate Committee on Appropriations
- The Honorable Patrick Leahy
  Vice Chairman, Senate Committee on Appropriations
- The Honorable Lamar Alexander
  Chairman, Energy and Water Development Subcommittee
  Senate Committee on Appropriations
- The Honorable Dianne Feinstein
  Ranking Member, Energy and Water Development Subcommittee
  Senate Committee on Appropriations
- The Honorable Lisa Murkowski
  Chairwoman, Senate Committee on Energy and Natural Resources
- The Honorable Maria Cantwell
  Ranking Member, Senate Committee on Energy and Natural Resources
- The Honorable Greg Walden
  Chairman, House Committee on Energy and Commerce
- The Honorable Frank Pallone, Jr.
  Ranking Member, House Committee on Energy and Commerce
- The Honorable Ron Johnson
  Chairman, Senate Committee on Homeland Security and Governmental Affairs
- The Honorable Claire McCaskill
  Ranking Member, Senate Committee on Homeland Security and Governmental Affairs
- The Honorable Michael McCaul
  Chairman, House Committee on Homeland Security

- The Honorable Bennie Thompson
  Ranking Member, House Committee on Homeland Security

If you have any questions or need additional information, please contact me or Mr. Robert Tuttle in the Office of Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Patricia A Hoffman

Patricia A. Hoffman
Office of Electricity Delivery and Energy Reliability

Executive Summary

Large power transformers (LPTs) are critical elements of the electric power transmission and distribution grid. LPTs pose unique vulnerabilities because of the long lead time it takes to manufacture and acquire replacements, and because of transformers' potential susceptibility to serious and evolving threats and hazards, ranging from isolated outages caused by physical attack to more severe events with the potential for widespread impact. Concerns about the vulnerabilities of LPTs have focused both government and industry attention on the need for a reserve capacity of transformers that would increase the ability of both individual utilities and industry partnerships to respond to adverse events and assure that the U.S. grid is increasingly resilient and able to recover quickly from widespread transformer failures.

This Report to Congress describes the national importance of a strategic transformer reserve, the results of a technical analysis conducted by Oak Ridge National Laboratory (ORNL), and current efforts underway by both industry and the government to mitigate potential threats to the U.S. bulk power grid created by the vulnerability of large power transformers. Based on the technical analysis and an examination of current efforts underway by industry and Government entities, the Department of Energy (DOE) evaluated options for establishing a strategic transformer reserve and recommends encouraging and supporting an industry-based option driven by voluntary industry actions and North American Electric Reliability Corporation's Reliability Standard CIP-014-2 requirements, approved by the Federal Energy Regulatory Commission (FERC).

DOE further recommends that within one year of the date of this report, it work with FERC and electricity industry partners to re-assess whether sufficient progress that has been made through this approach to warrant continuation or alternative actions by Government.

STRATEGIC TRANSFORMER RESERVE

Table of Contents

Page left intentionally blank

I. Legislative Language

This report responds to legislative language set forth in Section 61004 of the Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94), 129 Stat. 1780, wherein it is stated:

> *… "(1) PLAN.—Not later than 1 year after the date of enactment of this Act, the Secretary, acting through the Office of Electricity Delivery and Energy Reliability, shall, in consultation with the Federal Energy Regulatory Commission, the Electricity Sub-sector Coordinating Council, the Electric Reliability Organization, and owners and operators of critical electric infrastructure and defense and military installations, prepare and submit to Congress a plan to establish a Strategic Transformer Reserve for the storage, in strategically located facilities, of spare large power transformers and emergency mobile substations in sufficient numbers to temporarily replace critically damaged large power transformers and substations that are critical electric infrastructure or serve defense and military installations."*

II. National Importance of a Strategic Transformer Reserve

A. Background

Electricity is fundamental to most aspects of daily life in the United States, from running appliances to enabling communications and financial transactions, to powering and controlling industry operations. However, beyond its role as an everyday commodity expected to be extremely reliable, electricity is an essential part of public health and safety and national security, and is thereby considered a critical or "lifeline" function. Moreover, the other lifeline functions (telecommunications, transportation, and water) are dependent on electricity.

Thus, ensuring the resilience of the electric grid and its ability to recover from both localized and catastrophic events is sufficiently critical to the economy and national well-being that its provision goes beyond a purely private sector responsibility. While industry has proven that it can respond to a broad range of events affecting a local area or a small region, there remain concerns that more widespread events impacting a large number of large power transformers (LPTs) would be difficult for industry alone to handle with current spares and capabilities. The availability of spare LPTs and/or a strategic transformer reserve would help the United States respond to and recover from events with impacts greater than the nation has thus far experienced. Such high-impact occurrences could be caused by solar geomagnetic disturbances (GMD) or earthquakes, a large electromagnetic pulse (EMP) weapon, or multiple physical and cyberattacks, among others. If the electric grid sustained substantial damage, the process of replacing equipment such as LPTs would be costly and could take months, if not years.

LPTs are critical elements of the electric power transmission and distribution grid (see Figure 1). LPTs pose unique vulnerabilities because of the long lead time it takes to manufacture and acquire replacements, and because of transformers' potential susceptibility to serious and evolving threats and hazards, ranging from localized outages caused by physical attacks to more severe events with widespread potential impact . Concerns about the vulnerabilities of LPTs have focused both government and industry attention on evaluating the need for a reserve capacity of transformers that would increase the ability of both individual utilities and industry partnerships to respond to adverse events and assure that the United States (U.S.) grid is sufficiently resilient to recover from both localized as well as widespread transformer failures.

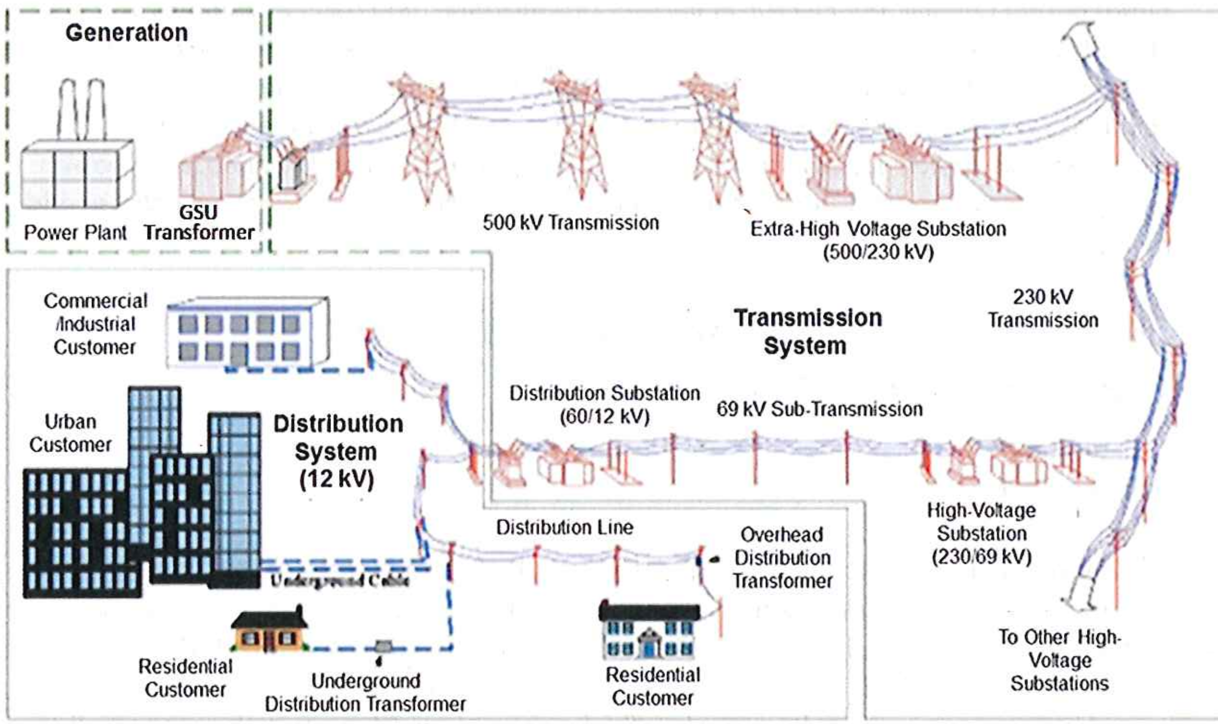

Figure 1: Electric Power Generation, Transmission, and Distribution

Thus, in April 2015 Department of Energy (DOE) Quadrennial Energy Review (QER) recommended that DOE analyze the technical specifications of a potential transformer reserve and assess existing industry equipment sharing efforts as part of a broader initiative to mitigate risks associated with the loss of one or more transformers. This recommendation focused both government and industry attention to the criticality of LPTs and issues related to their vulnerability to potential threats.

B. The FAST Act

Later that year, in December 2015, Congress and the President passed the FAST Act (Pub. L. No. 114-94), focused on improving the Nation's surface transportation infrastructure. The FAST Act directs DOE, plus government and industry partners, to establish and submit to Congress a plan for the creation of a strategic transformer reserve as quoted in Section I of this report. This Report to Congress is provided in response to the FAST Act direction.

Appendix I of this Report lists additional provisions of the FAST Act regarding the required content of a transformer reserve plan, to include a discussion of the degree to which utility sector actions or initiatives—including individual utility ownership of spare equipment, joint ownership of spare equipment inventory, sharing agreements, or other spare equipment reserves or arrangements—satisfy the requirements of the FAST Act.

C. A Formal Request for Information Regarding Transformers

In July 2015, the DOE Office of Electricity Delivery and Energy Reliability (OE) released a Request for Information (RFI) though the Federal Register seeking comments and information from interested parties to inform its policy development related to the possible establishment of a national reserve of power transformers that support the bulk power grid.[1] This RFI was an initial step in addressing the recommendation in the QER. The focus of the RFI was to solicit information pertinent to the design, implementation, need, and viability—regulatory, economic, and technical—of a strategic transformer reserve.

There were 26 responses from utilities, manufacturers, industry trade groups, and spare-equipment sharing programs. The RFI questions included whether there is a need for a national strategic transformer reserve, as well as what the requirements would be for such a reserve. The responses reflected the industry view that LPTs are critical to the reliability of the grid and that the availability of spares is a key element. Respondents strongly recommended that DOE work in coordination with all stakeholders, including the states, manufacturers, utilities, industry trade associations, and international/Canadian partners to leverage existing spare equipment sharing programs, and to ensure that a reserve would neither negate nor duplicate existing programs.

Respondents recommended that a strategic transformer reserve, if established, be owned and administered by the industry or even utilities themselves, with appropriate input or funding from the government. This would allow the utilities to leverage their procurement procedures and vendors; knowledge about LPT maintenance, storage, and transportation; and operational flexibility in their existing or planned investments in spare equipment. Respondents also indicated that the funding for deployment of LPTs should also be the responsibility of utilities themselves, though some respondents felt government funding is required.

[1] DOE RFI: July 2015 https://www.federalregister.gov/documents/2015/07/09/2015-16784/national-power-transformer-reserve

D. Technical Analysis and Industry Engagement

To determine the specific requirements for a strategic transformer reserve, DOE commissioned a technical analysis on the need for additional LPTs and related equipment and an assessment of ongoing government (e.g., Department of Homeland Security [DHS] and Federal Energy Regulatory Commission [FERC]) and industry efforts to meet transformer needs in the face of a significant national emergency in which multiple LPTs were destroyed. The findings of this analysis are summarized in this later in this report, along with a description of current Federal and industry efforts to ensure adequate access to LPTs.

E. Office of Electricity Delivery and Energy Reliability Meetings with Utilities and Other Partners

Concurrent with the technical analysis, OE leadership held several discussions with industry partners, including utilities, transformer manufacturers, and other Federal agencies.

In May 2016 OE hosted a webinar with over 100 participants from Federal, state, and local agencies; regulators; utility owners and operators; regional planning entities; transformer manufacturers; and industry organizations. The webinar provided an overview of the Oak Ridge National Laboratory (ORNL) approach to the technical analysis and addressed comments and questions from participants. A DOE email account was created by OE and the Energy Policy and Systems Analysis (EPSA) Office to receive additional comments and questions about the study, as well as correspondence regarding future events and reviews of draft materials.

In July 2016, an in-person meeting was held between the OE Assistant Secretary and some 60 utility and transformer companies to further discuss the strategic transformer reserve technical analysis and related topics. Assistant Secretary Hoffman acknowledged increased incidences of violence worldwide, making critical infrastructure more vulnerable today than it has been in past years. She stressed that as a result, the electric industry needs to revise its thinking on resilience and recovery. While it is may not be possible to make the grid 100% secure, it is important for our recovery strategies to be as comprehensive as possible, e.g., they must take into consideration how quickly supplies can be transported to critical locations, and how to restart facilities in emergency situations. Representatives from utilities, transformer manufacturers, and industry equipment sharing programs provided feedback on the ORNL study, posed questions to the ORNL team, and imparted insights on private sector activities regarding spare LPTs.

In August 2016, OE convened a meeting with government sector partners including DHS, the Department of Defense (DoD), FERC, the Department of Transportation (DOT), the Department of Commerce (DOC), Power Marketing Administrations, and the ORNL team. Attendees reviewed the study's progress and addressed comments from industry partners.

III. Results of Technical Analysis

In January 2016, DOE assigned the technical analysis of a strategic transformer reserve to a team led by Oak Ridge National Laboratory (ORNL). The project team included researchers and representatives from ORNL and the University of Tennessee-Knoxville, Sandia National Laboratory, the Electric Power Research Institute (EPRI), Dominion Virginia Power, the Southern Company, and the Western Area Power Administration.

The objective of the technical study was to determine if, after a severe malicious attack or natural disaster, extensive damage or destruction of LPTs and a potential lack of adequate replacement LPTs could render the grid dysfunctional for an extended period (several months to years) until replacement LPTs could be manufactured. ORNL identified the substations most crucial to the reliability of each interconnection. ORNL then determined how many spare LPTs exist that corresponded to the transformers in those crucial substations. The ORNL study provided technical input for a number of the FAST Act requirements.

The ORNL technical analysis methodology began by identifying the "crucial" substations in each interconnection, and the LPTs they contain. ORNL modeled the entire bulk power system, but due to time constraints the analysis examined the impacts of loss of the substations that are the backbone of each interconnection (500kV for Western - WI; 765 & 500kV for Eastern - EI; 345kV for Texas - TxI). For each substation, a load flow determined the impact on the interconnection's ability to meet demand if that substation's transformers were removed. The substations were then ranked according to this metric. The technical study then used the results of an industry survey conducted in 2016[2] to identify spare LPTs available to replace the LPTs in "crucial" substations. These spares were located in substations or in central locations managed by utilities.

The study:

- **Highlighted spare LPTs identified by industry, available to replace LPTs contained in crucial substations on the electricity transmission grid operating at each interconnection's highest voltage levels (765 and 500 kV in Eastern, 500 kV in Western, 345 kV in Texas).** Based on the results of a utility industry-led survey, ORNL identified the number of LPTs at voltages of 345 kV and higher that are designated as spare transformers by utilities. These spares are located and managed by utilities at substations or in central locations managed by utilities. However, industry did not share any specific locations due to concerns about the proprietary and sensitive nature of this information.

[2] See page 9 for further discussion of this industry-led survey.

- **Identified mechanisms used by utilities, in addition to the use of their own spare LPTs, to provide temporary LPTs and other replacement equipment to each other in a dire emergency (see Figure 2).** ORNL observed that the number of spare LPTs and individual utilities' access to them is increasing: utilities report they are purchasing additional spares; contracting with third party organizations (such as Grid Assurance) to create pools of critical equipment and supplies; strengthening mutual assistance agreements (such as the Spare Transformer Equipment Program (STEP)); and securely sharing information about available spares (e.g., through SpareConnect). Moreover, the study found that where no undamaged spare LPTs are available, most utilities have catastrophic emergency procedures in place to replace LPTs in crucial substations with operational LPTs taken from less crucial substations.

- **Reviewed use of provisional replacement transformer (PRT) substitutions.** PRTs are the operational LPTs moved from less critical substations; their use would be temporary (for up to a year or two) until a permanent replacement is available. While not a perfect design match to a damaged LPT, PRTs may be sufficient in terms of capacity, impedance and configuration, to be used temporarily to restore power to customers without power.

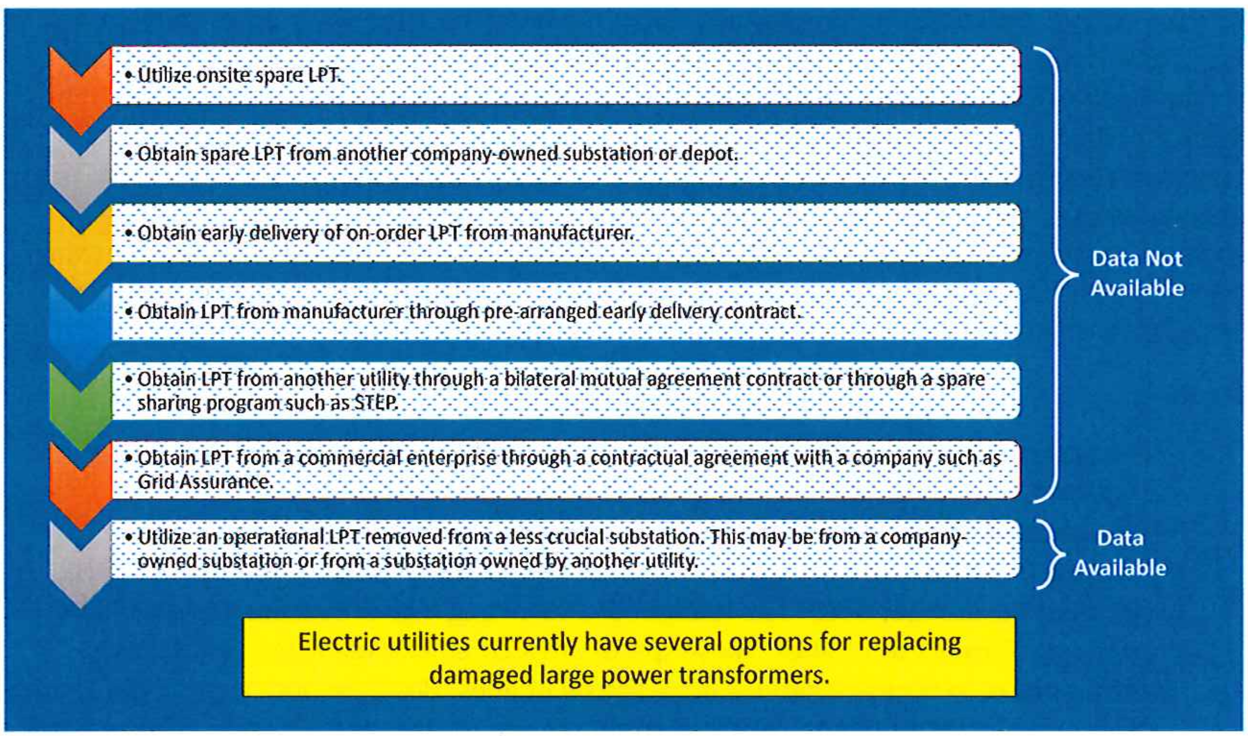

Figure 2: Electric Utilities' Options for Replacing Damaged Large Power Transformers

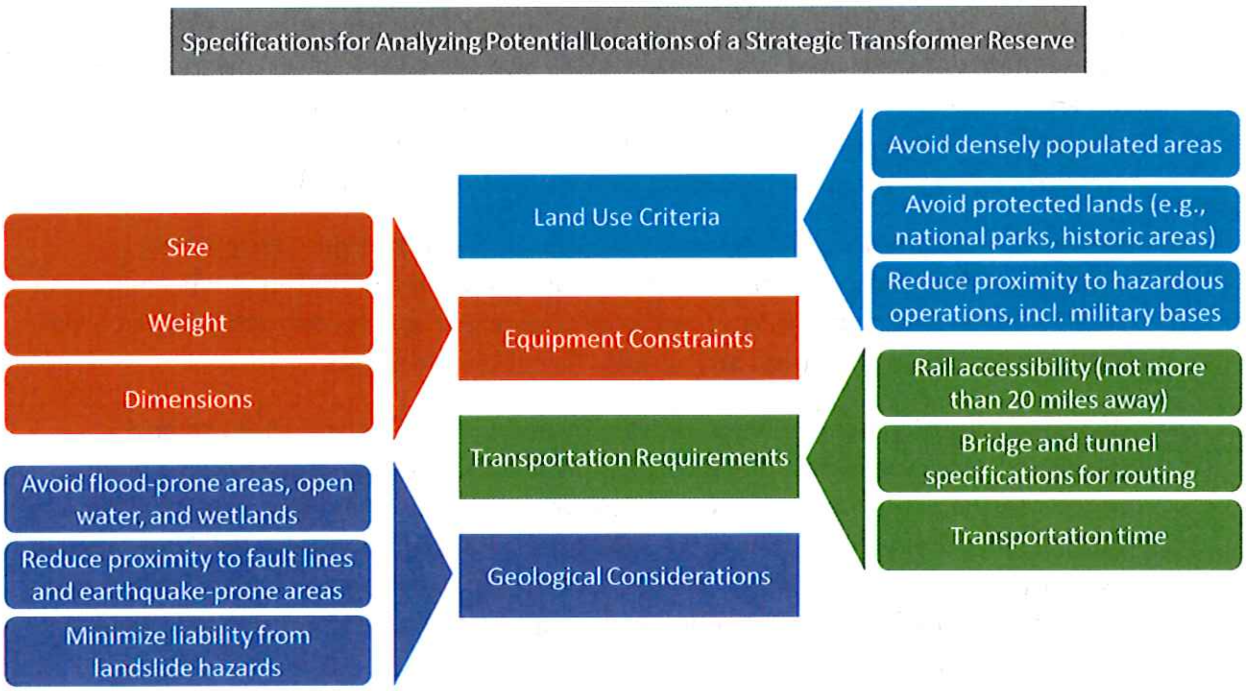

Figure 3: Criteria for Analyzing Potential Locations of a Strategic Transformer Reserve

- **Proposed criteria for evaluating potential locations of a transformer reserve (see Figure 3).** These criteria cover equipment and transportation constraints as well as the suitability of sites given land use and geological considerations.
- **Highlighted industry's transportation concerns and the need for a Federal role in facilitating spare LPT transport, especially in emergency conditions.** Transporting LPTs is time-consuming, requires particular routes and permits, and requires significant coordination with state and local authorities. This was the most frequently mentioned role for DOE as expressed by industry.
- **Identified that, in addition to transportation, adequate storage and installation of replacement LPTs are extremely crucial to establishing a functional strategic transformer reserve.** There are a number of important factors that require consideration, including the need for:
    - Maintenance staff
    - Security guards
    - Crews to disassemble/assemble, drain and refill oil, etc.
    - Cranes
    - Specialized road transport vehicles
    - Specialized rail cars: some very large transformers will need Schnabel rail cars
    - Availability of heavy haulers in different regions of U.S.
- **Identified other critical components will need to be addressed to restore electricity substations,** including bushings and circuit breakers.

- **Recognized that utilities individually plan to meet reliability and resilience requirements of their own service territories** (including their need to serve priority and critical loads), and to fulfill their obligations to the interconnected bulk power system (e.g., so loss of a utility's assets would not result in widespread instability, uncontrolled separation, or cascading within an interconnection).
- **Suggested examination of specific severe events** that are larger and/or more widespread than those now used for threat assessments to determine whether these could result in unacceptably long and large service disruptions on metropolitan areas. ORNL analysis did not address any specific threat or disruption.
- **Identified critical generator step-up transformers (GSUs)** as important to grid operations. They share manufacturing supply chains, material requirements, and transportation resource requirements. However, the vulnerabilities of generating stations differ from those of network substations. More information will be needed to assess the need for additional spare GSUs, including their specific characteristics and vulnerability profiles of crucial power generating stations, comparative lead times to replace GSUs, and the availability of spare GSUs.

The ORNL-led team made significant progress in understanding the need for a strategic transformer reserve; however, there are a number of areas that the study was not able to fully assess. These include: data on the number of existing un-energized spare LPTs that would have enabled ORNL to directly match available spares with individual LPTs designated as crucial, the need for additional spare generator step-up (GSU) transformers, and an analysis of all 100 MVA+ transformers and the potential impacts of their loss, including that of the 345 kV transformers outside of Texas.

IV. Activities Underway within Industry and Government

A. Individual Industry Initiatives

A number of resilience enhancement initiatives are underway at individual utilities directed specifically toward the stocking of spare transformers and related equipment. Within a utility, a spare transformer strategy may be implemented that includes stocking interchangeable spare transformers, ordering an extra inventory of conventional spares, and/or retiring transformers early so they can be employed as spares once the new equipment is installed. While all of these efforts are typically intended for individual unit failures, and are often co-located to minimize delays in energization, they offer greater flexibility in times of emergencies at one site or across a utility's territory.

B. Independent System Operators and Regional Transmission Organizations

At the regional level, Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) may require entities to maintain spare transformer inventories or direct owners and operators to keep spare equipment on hand. For instance, PJM's Regional Transmission Expansion Program (RTEP) requires owners and operators to procure a certain number of spare transformers based on a probabilistic risk assessment that measures the health of the existing inventory and the likelihood of a capacity emergency. Additionally, the Midcontinent Independent System Operator (MISO) requires owners and operators to provide descriptions of their spare inventories as well as any mutual sharing agreements they have signed, and the California Independent System Operator (CAISO) requests emergency operating plans and resources for responding to major events.

C. Collaborative Industry Efforts

Across the industry, consortia and companies are being established to implement sparing approaches, particularly the sharing of transformers and other associated equipment in the event of major disruptions to the grid. Often, these programs involve cooperation on a regional basis, incorporating transportation and other logistical considerations. An overview of some of these programs is provided below.

- **Utility Industry Survey of Very Large Spare Transformers**
  In 2016, the Edison Electric Institute, the American Public Power Association and the National Rural Electricity Cooperative Association, at the request of DOE, conducted a survey of their members, asking each to identify "spare LPTs" available to replace LPTs that were contained in "crucial" substations. The survey identified LPTs at voltages 345 kV and higher designated as "spare" transformers by utilities. These spares were located in substations or in central locations managed by utilities. This effort served as the basis for the ORNL technical analysis discussed earlier in this report.

- **Spare Transformer Equipment Program (STEP)**
  Edison Electric Institute (EEI) established the STEP program. STEP requires participating utilities to maintain (and sometimes acquire) a specific number of transformers up to 500 kV to be made available to other utilities in case of a critical substation failure. Sharing of transformers is mandatory based on a binding contract subject to a "triggering event"—a coordinated act of deliberate, documented terrorism resulting in the destruction or disabling of a transmission substation and the declaration of a state of emergency by the President.

  Participants of STEP sign a binding contract called the *Spare Transformer Sharing Agreement* that establishes the governance of the program and provides strict confidentiality provisions to ensure that participating utilities' information is protected. Under this Agreement, each participating utility is obligated to commit a certain MVA capacity of spare transformers for each voltage class in which it is a member. The quantity committed is based upon the size of the utility and the utility's self-assessment of its ability to restore the system to minimal, but not normal operating conditions in the event of losing its five most critical substations per voltage class. Thus, STEP enables participating utilities the ability, at a minimum, to recover from the simultaneous loss of up to five of their substations. In some cases, utilities have committed additional spares beyond their requirement, thus giving the program the ability to support the recovery of more than five substations per voltage class.

As of March 2016, 56 electric utilities were members of STEP. Reportedly, these companies served over 98 million residential, industrial, and commercial customers, which comprise approximately 67% of U.S. electricity customers. To participate in STEP, each participating utility pays an enrollment fee of $10,000 and annual dues of $7,500. FERC and state commissions have issued orders approving participation and cost recovery.

The program is designed to respond to terrorist events, but it also provides a mechanism for voluntary sharing of transformers in other emergencies, although these may require additional regulatory approvals. EEI requires annual recertification and conducts a STEP program drill every summer to ensure the program and its members are fully prepared to respond in the event of an actual triggering event.

- **SpareConnect**
  EEI also established the SpareConnect program. Both STEP and SpareConnect require participants to already own physical assets, and have established criteria for deploying spare transformers. However, SpareConnect is less formal than STEP, building on existing communication channels between utilities and allowing them to connect regarding equipment and other technical needs during an emergency or other non-routine failure. In addition, SpareConnect is designed for emergency events unrelated to terrorist activity. Through SpareConnect's confidential online platform, the entire electric industry can reach out to other members, complementing utilities' own spare programs, as well as existing programs such as STEP and voluntary mutual assistance programs.

  Because the program relies on shared industry resources, SpareConnect does not manage its own central database of spares. Instead, it serves as a conduit for points of contact at various utilities so that in case of an emergency, members can quickly connect with other participants in the same voltage class who can provide backup equipment. Utilities that have been matched then discuss specific arrangements such as terms and conditions or transportation. Lastly, SpareConnect remains a voluntary, mutually cooperative program, and does not obligate any participants to provide information or equipment.

- **Grid Assurance**
Grid Assurance is a company formed by utilities and energy companies with the goal of developing a more cost-effective cooperative method to procure additional spare equipment instead of utilities acquiring spares on their own. The founding partners include some of the largest energy companies in the United States, including American Electric Power, Berkshire Hathaway Energy (BHE), Duke Energy, Edison Transmission (Edison International), Eversource Energy, and Great Plains Energy. Grid Assurance intends to maintain a large-scale inventory of spare transmission equipment that is ready for rapid deployment to any of its subscribers in case of an emergency. The service is similar to STEP, but aims to be more comprehensive, providing spares for related equipment as well as transformers and covering a wider range of situations than just terrorist attacks.

  Grid Assurance is expected to be fully functional by January 2018. The program expects to maintain an inventory of at least 100 transformers that each cost between $2 million and $10 million. In March 2016, FERC found that subscribing to the Grid Assurance sparing service and purchasing equipment from Grid Assurance in an emergency are prudent. FERC also ruled that subscribers would not have to pursue full rate cases to recover related costs, but instead could use single-issue ratemaking.[3]

- **Wattstock**
An independent private company, Wattstock, developed the Transformer Recovery Inventory Program (TRIP) to enhance spare coverage for the industry. The company claims that TRIP will offer more transparent pricing and terms with better coverage, service, and performance than other industry programs. The STEP program, as well as the Pooled Inventory Management program, an emergency equipment sharing arrangement for the nuclear industry, have set regulatory precedents for recouping investment in the TRIP program.

  The goal of the TRIP program is to build a national inventory of LPT spares, comprised of 60 to 100 modular Wattstock Recovery Flex Transformers (RFT) located at regional distribution centers. Participants pay an enrollment fee and annual membership, as well as a rental fee for usage of spares, with an option for purchasing the spare. Wattstock asserts that a spare unit can be shipped and installed within two to three weeks of an emergency event. TRIP currently offers nine generator step-up transformer models, claimed to represent 97 percent of the traditional MVAs in the market. For

[3] 154 FERC ¶ 61,244. March 25, 2016. Available at: https://www.ferc.gov/CalendarFiles/20160325163047-EL16-20-000.pdf.

transmission transformers, TRIP intends to offer five models, which represent 2000 transmission transformers.

- **Restore**

  Further indicative of the change occurring within the industry, in November 2016, the Southern Company, along with Louisville Gas and Electric Company and Kentucky Utilities Company, PPL Electric Utilities, and the Tennessee Valley Authority, announced a regionally focused initiative to enhance the resiliency and reliability of the power grid by providing additional sources for obtaining critical equipment following disastrous events based largely on mutual aid agreements.

  The initiative is known as RESTORE (Regional Equipment Sharing for Transmission Outage Restoration), and establishes a voluntary program in which participants identify spare transformers and other transmission equipment that would be made available for purchase by other participants if they experience a widespread disaster or physical attack within their service area. The RESTORE program is intended to expand to include other utilities in the region and to complement rather than replace other industry programs or internal sparing processes. The full timeline for implementation of this program has not been released.

D. Transformer Transportation Working Group

The success of industry LPT sharing programs depends on the industry's capability to move spare transformers quickly in the event of an emergency, as does the success of an individual utility's plans. A Transformer Transportation Working Group (TTWG) was established in 2014 at the request of the Electricity Subsector Coordinating Council (ESCC)[4] to identify opportunities to speed LPT transportation. Consisting of over 70 industry executives, the TTWG has been meeting with utility industry programs, trade associations, representatives from the Federal Government, representatives from the rail and road sectors, and transformer manufacturers to identify opportunities and create tools to speed the transport of LPTs in an emergency.

The following areas have been identified by the TTWG to expedite transformer transportation:

- Developing a transformer transportation emergency support guide with input from utilities, Class I railroads, and the heavy hauler industry to expedite the deployment of transportation equipment and services that would be needed to move LTPTs.
- Continuing to develop public-private partnerships with key Federal agencies including DOE, DHS and its Federal Emergency Management Agency, DOT, and DoD. Reaching out to Federal and state transportation agencies, as well as transportation sector

[4] The Electricity Subsector Coordinating Council (ESCC) is an industry-organized group of utility Chief Executive Officers and trade industry leadership which meets three times a year with senior government officials. Its charter can be found at: https://www.dhs.gov/publication/energy-sector-council-charters

trade groups, to better understand how the permit review process could improve LPT movement.

- Working with the National Guard as well as law enforcement groups to determine how these agencies can provide enhanced security support to the industry in an emergency.
- Testing communication and emergency response plans with the transportation sector and Federal Government through drills and exercises.

E. U.S Department of Energy Activities

DOE's Office of Electricity Delivery and Energy Reliability has undertaken a number of efforts focusing on improving transformer and overall grid resilience.

Assessment of Large Power Transformer Manufacturers

DOE issued a study of Large Power Transformers and the U.S. Electric Grid in 2014 which reviewed the state of domestic and international manufacturing to identify issues of possible concern.[5] Among the conclusions of this report were:

- Transformer manufacturers and utilities are working to develop lighter weight, more easily transportable LPTs. Currently, only one 345 kV LPT mobile (lighter weight and more transportable) transformer is available from a single manufacturer. Other transformer manufacturers are developing approaches to speed LPT replacement and flexibility. For example, a manufacturer of smaller, distribution-level transformers intends to develop larger mobile transformers and substations.

- LPTs are custom-engineered equipment that entail a significant capital expenditure and long lead times due to an intricate design, procurement, and manufacturing process (see Figure 4). Although prices vary by manufacturer and by size, an LPT can cost millions of dollars and weigh between 100 and 400 tons. The engineering design, procurement, and manufacturing of LPTs is a complicated process that includes the prequalification of manufacturers, a competitive bidding process, the purchase of raw materials, and special modes of transportation due to their size and weight. The result is the possibility of an extended lead time that could stretch beyond 8 to 12 months if the manufacturer has difficulty obtaining certain key parts or materials or if the ordering queue is backed up.

[5] The report is available at https://www.energy.gov/oe/articles/update-large-power-transformers-and-us-electric-grid-report-now-available.

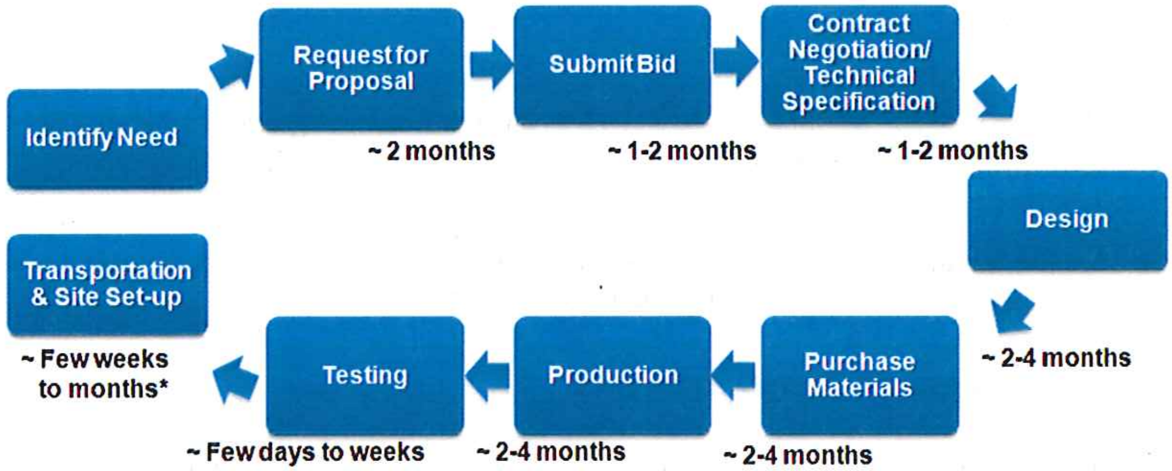

Figure 4: Representative Transformer Manufacturing Timeline

- The United States has had limited domestic production capacity for LPTs and has heavily relied on foreign suppliers; reported procurement of LPTs from abroad has in recent years been as high as 85 percent. However, domestic production capacity for LPTs has improved. Since April 2010, four new or expanded facilities have begun producing LPTs in the United States, including: Georgia Transformer Corporation in Rincon, Georgia; Hyundai Heavy Industries in Montgomery, Alabama; SPX Transformer Solutions in Waukesha, Wisconsin; Mitsubishi Electric Corporation in Memphis, Tennessee; and the ABB Group in St. Louis, Missouri.

- While global procurement has been a common practice for many utilities and generators to meet their need for LPTs, there are several challenges associated with it. Challenges include the potential for an extended lead time due to unexpected global events or difficulty in transportation competing orders from foreign utilities. The energy industry is also facing the challenge of maintaining an experienced in-house workforce that is able to address procurement and maintenance issues.

- High-voltage bushings are also known to have long lead times and limited supplier sources. Two raw materials, copper and electrical steel, account for more than half of the total cost of LPT materials. Special grade electrical steel is used for the core of a power transformer and is critical to the efficiency and performance of the equipment; AK Steel in Westchester Ohio is currently the only domestic manufacturer. Furthermore, a specially manufactured copper conductor is used for the windings. The price volatility of these commodities in the global market can affect the manufacturing condition and procurement strategy for LPTs.

DOE Transformer Resilience and Advanced Components Program

Transformers, power lines, and substation equipment are often exposed to the elements and are vulnerable to an increasing number of natural and manmade threats. Advanced grid hardware needs to be designed and built to better withstand and rapidly recover from the impact of lightning strikes, extreme terrestrial or space weather events, electrical disturbances, accidents, equipment failures, deliberate attacks, and other unknowns. This will ensure a reliable and resilient electric power system and achieve the full value of ongoing grid modernization, Next-generation technologies can improve the performance and lifetime of transformers and other equipment over current designs, and unleash new and expanded capabilities for the grid.

To help address this need, DOE is establishing the Transformer Resilience and Advanced Components (TRAC) program, which aims to accelerate modernization of the grid by addressing challenges to LPTs and other critical grid components. With $5 million of funding in 2016 and a request for $15 million in 2017, TRAC will support research and development to understand the physical impact that the evolving grid will have on LPTs and other equipment, and will encourage the adoption of new technologies and approaches. Most recently, TRAC made five awards totaling mote that $1.5 million to stimulate innovative LPT designs that are more flexible and adaptable so they can be readily used in different substations. These designs will increase the ability to share transformers and accelerate recovery in the event of the loss of one or more transformers. The awarded projects are:

- **Modular Controllable Transformers for a Resilient Grid.** *Georgia Tech Research Corporation, with Oak Ridge National Laboratory, Delta Star, and Southern Company.* This project will design an innovative modular controllable transformer that can be paralleled as needed to realize a range of higher power ratings (100-500 MVA), supporting continued grid operations under single or multiple transformer failures and provide flexibility in terms of configuration, load balancing, ease of transportation, and faster restoration time following a large outage.
- **A Modular and Flexible High-Frequency-Link Transformer with 63% Reduction in Device Count and Zero High-Side Devices.** *NextWatt, the National Center for Reliable Electric Power at the University of Arkansas, and General Electric.* This project will explore the design of a solid-state, modular high frequency link LPT rated at 100 MVA with a high-side voltage of 115 kV, variable low-side voltage, and variable impedance capability. The design can provide a three times reduction in both volume and weight compare to a conventional LPT, easing transportation concerns.
- **Grid Ready, Flexible Large Power Transformer.** *General Electric Global Research and Prolec GE.* This project will design a flexible LPT capable of accommodating multiple standard voltage ratios in the transmission network as well as providing an adjustable impedance to match that of a failed LPT. The key innovations in this project include multiple transmission class voltage taps at the low voltage side; a method for selecting the transformer impedance without changing the voltage ratio; and arrangement and connection of all the extra windings to minimize stresses.
- **Novel Concept for Flexible and Resilient Large Power Transformers.** *ABB Inc. with University of Tennessee-Knoxville.* This project will investigate the feasibility of

constructing, installing, and servicing flexible LPTs comprised of easily transportable, standardized building blocks which house several transformer modules. This concept creates a blueprint for future LPTs that can quickly and effectively replace a variety of existing LPTs.

- **Flexible Large Power Solid State Transformer.** *North Carolina State University and Carnegie Mellon University.* The concept of Flexible Large Power Solid State Transformer is proposed to achieve greater standardization to increase grid resilience through a modular solution. The use of standard building blocks can reduce manufacturing, inventory, and transportation costs and enable greater interchangeability. Moreover, the amount of raw materials needed (copper and magnetics) can be significantly reduced.

F. Additional Federal Efforts

In addition to DOE's efforts and individual and collaborative industry initiatives, there are also further Federal measures and R&D aimed at supporting and enhancing grid security on the part of owners and operators. A number of Presidential Policy Directives and Executive Orders also address critical infrastructure security and resilience, cybersecurity, and preparedness.

U.S. Department of Homeland Security

Some manufacturers are engaged in the development of flexible spare transformers of various types. DHS' Science & Technology Directorate, EPRI, ABB, and CenterPoint Energy (CNP), developed the Recovery Transformer (RecX), a prototype LPT that would drastically reduce the recovery time for damaged LPTs. The RecX is single-phase, which allows it to be transported in triples each weighing 125,000 pounds; this results in a smaller and lighter solution that is easier to transport than a traditional 400,000 pound three-phase LPT. Installation time is also reduced. Prior to installation in CNP's grid in March 2012, the RecX was fully piloted.
Transportation, installation, assembly, commissioning, and energization of the RecX took less than one week. The RecX was designed to be a suitable replacement for more than 90 percent of 345:138kV, 200 MVA per phase LPTs (equivalent to 600 MVA) but to-date no additional units have been purchased from the manufacturer and no larger REC-X type transformers have been manufactured.

Federal Energy Regulatory Commission

FERC approved the North American Electric Reliability Corporation's (NERC) Critical Infrastructure Protection (CIP) -014-2 Reliability Standard on November 20, 2014. CIP-014-2 requires utilities to create plans to protect, transmission stations and substations, and their associated primary control centers that, if rendered inoperable or damaged as a result of a physical attack, could result in instability, uncontrolled separation, or cascading within an interconnection.

CIP-014-2 requires that transmission owners and operators identify their transmission stations and substations critical to grid stability, evaluate the vulnerability of their facilities to physical attack, and develop and implement documented physical security plans. The required elements of a plan include resilience and security measures, law enforcement contact and coordination information, a timeline for executing the plan, and provisions for addressing evolving threats. CIP-014-2 also requires the transmission owners and operators subject to the standard to engage unaffiliated third-parties to verify their analyses and review their plans.

Reliability standard EOP-010-1 on Geomagnetic Disturbance (GMD) , was instituted to address solar events (i.e., storms or flares) that alter the electric currents in the earth's magnetic field and can have a large impact on the reliability of electric systems. In extreme cases, geomagnetic -induced currents from a solar storm could flow through transmission lines. In the past, GMDs damaged essential equipment. Much more is known now about GMDs, and operating procedures for dealing with GMDs are far better defined, reducing some of the risk.
Each Planning Coordinator, in conjunction with its Transmission Planner(s), shall identify the individual and joint responsibilities of the Planning Coordinator and Transmission Planner(s) in the Planning Coordinator's planning area for maintaining models and performing the study or studies needed to complete GMD Vulnerability Assessment(s).

As with the CIP-014-2 standard, EOP-010-1 requires entities to develop and implement appropriate operating procedures to mitigate potential impacts from an event, in this case GMD. The standard applies to transmission operators with an operation area that includes high side wye-grounded power transformers with terminal voltage greater than 200 kV and to reliability coordinators. Transmission operators are required to develop, maintain, and implement operating procedures to mitigate the effects of GMD events. Reliability coordinators are required to develop, maintain, and implement plans that coordinate the procedures of the operators within their areas.

Approved on September 22, 2016, reliability standard, TPL-007-1: Transmission System Planned Performance for Geomagnetic Disturbance Events, requires certain transmission and generator owners, planning coordinators, and transmission planners to assess the vulnerability of their system to a benchmark GMD event (a "one-in-100-year" event). If an assessment indicates that a system does not meet the performance requirements, the responsible entity would have to develop a corrective action plan addressing how it will meet the requirements. The standard requires entities to have system models needed to complete periodic vulnerability assessments and criteria for acceptable steady state voltage performance during a benchmark GMD event.

Taken together, these standards could form the basis for improved substation resilience that would address a variety of threats.

V. Transformer Reserve Options

In accordance with the requirements of the FAST Act, DOE considered a variety of options for a strategic transformer reserve, as well as their implications.

A. Federally-Owned Reserve

Establishing a wholly Federally-owned reserve, with DOE as the lead Federal agency, would face a significant number of challenges with respect to cost, location, transportation, maintenance, potential adverse market effects and industry acceptability.

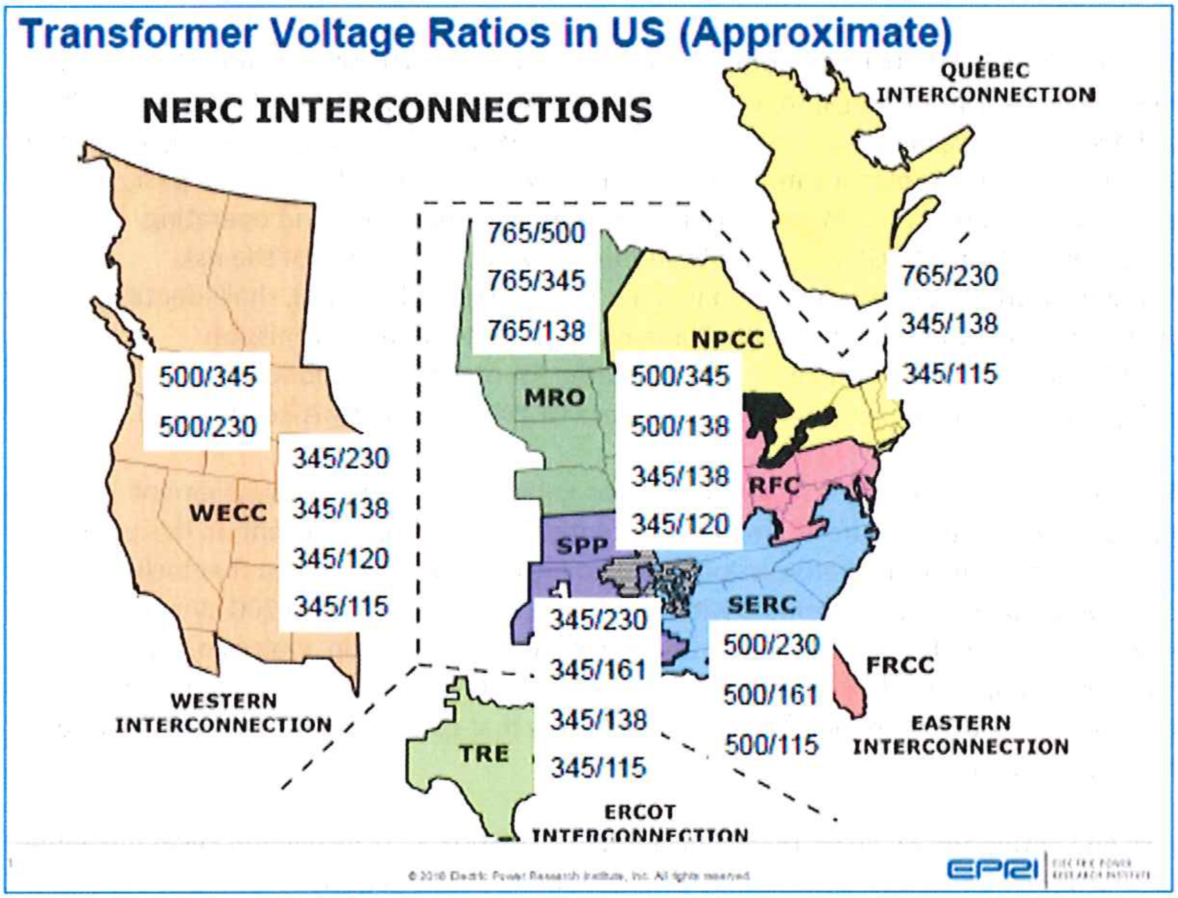

Figure 5. Principal LPT Voltage Ratios by NERC Region

The purchased pool of LPTs might need to be in excess of 100+, as suggested by an informal Western Area Power Administration analysis, in order to cover wide voltage ranges (see Figure 5), capacities, single and three-phase units, busing configurations, impedances etc. The cost of these LPTs range between \$2-\$7 million per transformer, depending on their size and specifications, and thus their acquisition would require significant resources and time to build. Based on industry information, the majority of LPTs currently are imported from transformer manufacturing plants outside of the U.S., adding additional complexity to this challenge. If the new demand associated with establishing a formal reserve were not properly phased in over time, the sudden increase in demand could increase prices both for the reserve and for individual utility purchases. Finally, an LPT reserve would not be sufficient; other critical, long-lead time equipment like bushings and breakers would also be needed, as would the operational infrastructure to manage such a reserve in which the equipment must routinely be tested, maintained, and refreshed.

Industry engagement and information-sharing also would be critical to design the reserve with the appropriate regional optimization to ensure the availability of suitable sizes, impedances, and designs. To-date industry has been reticent to provide the level of detailed information that would be needed to design an effective federal reserve. Notwithstanding industry reticence, the federal government has authority to compel the disclosure of certain information from the industry. In addition to DOE's authority to compel disclosure, both FERC and the Bureau of Industry and Security at the U.S. Department of Commerce have certain authority to obtain information on matters related to security and reliability.

A Federally-owned program would need five or more geographically diverse utility sites nation-wide to minimize transportation delays and costs and serve as secure, storage depots. Transportation planning would need to include rail cars and vehicles, permits, personnel, and other equipment, and these would need to incorporate pre-determined logistics plans on how equipment would be deployed in the event of an emergency.

The cost of a federal reserve would be significant. Using the midpoint price of a transformer ($4.5M) and the estimated number of transformers (100+), the minimum cost would be $450M, just for the procurement of the transformers. Added to this would be the costs of transport to the storage locations (in some cases roadways and bridges would require reinforcement to carry very heavy transformers), storage, routine testing and maintenance, and security. This would likely put the overall cost well over $500M.

B. Enhancing Industry-Based Approaches

Given the work already underway by industry described in this report, a second option for ensuring a ready and sufficient supply of spare LPTs would be enhancing and expediting current industry-led approaches, and working to ensure that all, especially smaller, utilities would benefit.

This approach could establish the set of covered transformers as equivalent to facilities deemed critical under CIP-014, and DOE would work with industry and others to ensure adequate plans for resilience of these transformers. The exact strategies for how this would be accomplished would be left to individual utilities or groups of utilities by ISO or RTO. Because of the differences in the number and location of each utility's facilities, ranges of loads served, generation mix, and unique vulnerabilities, utilities should be given the flexibility to tailor their plans to meet their individual situations. Specifying a uniform requirement would not offer this flexibility. In addition, FERC has permitted cost recovery on certain utility investment for infrastructure security and resiliency. For example, FERC has approved such investments for LPTs and associated assets, as illustrated by recent FERC orders concerning Grid Assurance.

Under this approach, DOE as the lead Federal agency would convene Federal stakeholders, transformer manufacturers, utilities, trade associations, and others to define and detail the approach, and to ensure representation and coverage of the smaller utilities, municipals, and cooperatives in defining and addressing their unique resilience goals. Government agencies would work with industry to examine and, as appropriate, update the relevant NERC CIP/TPL standards, to make sure utilities are providing for sufficient spare LPTs. This would entail industry continuing to develop plans to address the potential risks and vulnerabilities, and subsequently submitting those plans for independent review.

This new approach should be built on several existing efforts including:

- FERC's approval of CIP-014-2, which requires investor-owned utilities and other transmission owning entities under FERC's jurisdiction to perform risk assessments to identify their most critical transmission stations and substations (i.e., those that if rendered inoperable or damaged could result in widespread instability, uncontrolled separation, or cascading outages) and develop a plan to protect these stations and substations from potential threats by late 2016. Some utilities have already taken steps (after the PG&E Metcalf incident in California) to increase substation security. These efforts might form a basis for prioritizing the LPTs that need enhanced resilience and for determining the content of the plans that will be submitted. DOE should consider allowing priorities to be set at the ISO/RTO level.
- Grid Assurance's efforts could be expanded or modeled by other companies; other commercial enterprises such as Delta Star, which builds smaller size mobile transformers and substations, could likewise be expanded to include larger transformers. Likewise cooperative efforts and mutual assistance arrangements. such as STEP and RESTORE could be encouraged.
- DOE could work with utilities to support R&D for additional grid resilience of critical components and long-term industry specifications to encourage utilities to move towards greater standardization of LPT designs and incorporation of more resilient elements to make spare LPTs more interchangeable. This would promote increased resilience without necessitating large reserves of LPTs covering the range of voltages and configurations needed.
- DOE could facilitate the transportation of transformers, particularly during emergencies, by supporting and implementing the recommendations of the TTWG. These recommendations include collaboratively:
    - Developing a transformer transportation emergency support guide.
    - Understanding how the permit review process could improve LPT movement.
    - Testing communication and emergency response plans through drills and exercises.

For this option, the costs to the Federal Government would be driven by the research programs run by DOE and others; assessments of the scenarios that the reserves should be designed to cover; the efforts to enable transportation of LPTs in times of need: and FERC's development and compliance oversight of the performance standards for industry. These costs are significantly lower than those for the procurement of a full reserve of transformers.

An approach to ensuring an adequate supply of LPT capacity that builds on existing Federal standards and industry-led activities would have numerous advantages, including greater flexibility to industry, lower federal costs, and expedited application. Key will be finding ways to assure that federal resiliency standards are met, and that assistance is provided to smaller utilities so that they may participate fully.

VI. Conclusions and Proposed Next Steps

To protect public health and safety, enhance national security, and ensure the resilience of the Nation's electric grid, there is an imperative to take actions that require industry and government to increase grid resilience, such as the measures called out in the FAST Act. However, DOE does not recommend creation of a Federally-owned reserve. Rather, the most efficient and effective approach is one which builds on industry-based approaches and their ongoing efforts to achieve greater transformer resilience in the face of the evolving threats. This approach would combine application of NERC Reliability Standards (e.g., CIP-014) and enhanced partnerships between government and the utility industry (including the ESCC), operators of sparing programs, and equipment manufacturers to facilitate the creation of a transformer reserve strategy that meets the needs of the Nation and benefits all utilities regardless of size.

Based on FERC data, utility industry cooperation, and the technical analysis conducted by the ORNL team, it appears that there are more un-energized LPTs available to industry than were previously recognized. Certain industry programs such as EEI's STEP program can be activated formally in a terrorist event and non-disclosure agreements have been signed in advance between all utility participants. Relatively recent companies and programs such as Wattstock, Grid Assurance, and RESTORE are supplementing the more established programs like STEP and SpareConnect. The NERC standards provide additional guidance on ensuring resilience to owners and operators. Such programs collectively support an industry-led solution as best positioned to meet transmission owner and operator needs.

To this end, DOE proposes working in close collaboration with the utility industry to:

- Develop a mechanism for independently assessing resilience of critical transformers, which could be those at facilities deemed critical under CIP-014.

- Create scenarios on impacts and threats to specific regions that will inform the development of NERC performance-based standards, overseen by FERC.
- Establish performance measures to reflect individual and collective progress in building resiliency.
- Support the creation of regional organizations to support increased cooperation and resilience, which would then enable all utilities to partake in various sparing programs. Other forms of support might include grants or other funding mechanisms.
- Understand and provide the nature of technical support and other incentives needed by small utilities, municipals, and cooperatives to enable their participation in industry-led efforts.
- Coordinate with the industry-led Transformer Transportation Working Group to improve and optimize transportation planning in response to a significant national event impacting the electricity grid.

Throughout these efforts, DOE would continue to work with asset owners and operators, as well as transformer manufacturers, and encourage more cooperative government/industry R&D to support the development and testing of more resilient designs and design changes to improve flexibility in the event of an emergency. DOE would continue to encourage transformer manufacturers to improve their products by developing units that would meet high resilience standards to GMDs and EMPs, as well as physical and cyber threats. Finally, DOE would continue to support advanced R&D in conjunction with ongoing grid modernization through a cost-shared program with industry.

Appendix I – Legislative Requirements: Strategic Transformer Reserve

The FAST Act calls for:

(2) INCLUSIONS.—The Strategic Transformer Reserve plan shall include a description of—

(A) the appropriate number and type of spare large power transformers necessary to provide or restore sufficient resiliency to the bulk-power system, critical electric infrastructure, and defense and military installations to mitigate significant impacts to the electric grid resulting from—

(i) physical attack;
(ii) cyber attack;
(iii) electromagnetic pulse attack;
(iv) geomagnetic disturbances;
(v) severe weather; or
(vi) seismic events;

(B) other critical electric grid equipment for which an inventory of spare equipment, including emergency mobile substations, is necessary to provide or restore sufficient resiliency to the bulk-power system, critical electric infrastructure, and defense and military installations;

(C) the degree to which utility sector actions or initiatives, including individual utility ownership of spare equipment, joint ownership of spare equipment inventory, sharing agreements, or other spare equipment reserves or arrangements, satisfy the needs identified under subparagraphs (A) and (B);

(D) the potential locations for, and feasibility and appropriate number of, strategic storage locations for reserve equipment, including consideration of—

(i) the physical security of such locations;
(ii) the protection of the confidentiality of such locations; and
(iii) the proximity of such locations to sites of potentially critically damaged large power transformers and substations that are critical electric infrastructure or serve defense and military installations, so as to enable efficient delivery of equipment to such sites;

(E) the necessary degree of flexibility of spare large power transformers to be included in the Strategic Transformer Reserve to conform to different substation configurations, including consideration of transformer—

(i) power and voltage rating for each winding;
(ii) overload requirements;
(iii) impedance between windings;
(iv) configuration of windings; and
(v) tap requirements;

(F) an estimate of the direct cost of the Strategic Transformer Reserve, as proposed, including—

(i) the cost of storage facilities;
(ii) the cost of the equipment; and
(iii) management, maintenance, and operation costs;

(G) the funding options available to establish, stock, manage, and maintain the Strategic Transformer Reserve, including consideration of fees on owners and operators of bulk-power system facilities, critical electric infrastructure, and defense and military installations relying on the Strategic Transformer Reserve, use of Federal appropriations, and public-private cost-sharing options;

(H) the ease and speed of transportation, installation, and energization of spare large power transformers to be included in the Strategic Transformer Reserve, including consideration of factors such as—

(i) transformer transportation weight;
(ii) transformer size;
(iii) topology of critical substations;
(iv) availability of appropriate transformer mounting pads;
(v) flexibility of the spare large power transformers as described in subparagraph (E); and
(vi) ability to rapidly transition a spare large power transformer from storage to energization;

(I) eligibility criteria for withdrawal of equipment from the Strategic Transformer Reserve;

(J) the process by which owners or operators of critically damaged large power transformers or substations that are critical electric infrastructure or serve defense and military installations may apply for a withdrawal from the Strategic Transformer Reserve;

(K) the process by which equipment withdrawn from the Strategic Transformer Reserve is returned to the Strategic Transformer Reserve or is replaced;

(L) possible fees to be paid by users of equipment withdrawn from the Strategic Transformer Reserve;

(M) possible fees to be paid by owners and operators of large power transformers and substations that are critical electric infrastructure or serve defense and military installations to cover operating costs of the Strategic Transformer Reserve;

(N) the domestic and international large power transformer supply chain;

(O) the potential reliability, cost, and operational benefits of including emergency mobile substations in any Strategic Transformer Reserve established under this section; and

(P) other considerations for designing, constructing, stocking, funding, and managing the Strategic Transformer Reserve.