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Comment:	Dear Secretary Hoffman, On behalf of the Power Transformer Section of the National Electrical Manufacturers Association (NEMA), I am pleased to submit the attached comments in

response to the request for information issued by the U.S. Department of Energy to inform its policy development related to the possible establishment of a national reserve of power transformers that support the bulk power grid. Large power transformers are essential components of the electric grid that control the high-voltage flow of our nations electricity. Because these transformers are essential to the function of the bulk power system, the grid is vulnerable to a coordinated attack or natural disaster impacting multiple transformers that could result in widespread and prolonged electricity outages. NEMA recommends that the U.S. Departments of Energy and Homeland Security and the Federal Energy Regulatory Commission work with bulk power system owners/operators, utilities, manufacturers, state public utility commissions, and other stakeholders to establish a national strategy that includes regional pools of transformer equipment reserves that are strategically placed to enable the prompt restoration of the bulk power system in the event of a natural disaster, physical attack, cyberattack, or other unforeseen emergency that results in the catastrophic failure of multiple large power transformers. If you have any questions about our comments, please contact Patrick Hughes, Director of Government Relations, at 703-841-3205 or patrick.hughes@nema.org. Sincerely, Kyle Pitsor Vice President, Government Relations *

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National Electrical Manufacturers Association

Representing Electrical and Medical Imaging Equipment Manufacturers
www.nema.org

August 24, 2015

Patricia A. Hoffman
Assistant Secretary
Office of Electricity Delivery and Energy Reliability
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

Re: NEMA Comments on the National Power Transformer Reserve Request for Information; 80 FR 39422 of July 9, 2015

Dear Secretary Hoffman,

On behalf of the Power Transformer Section of the National Electrical Manufacturers Association (NEMA), I am pleased to submit our comments in response to the request for information issued by the U.S. Department of Energy to inform its policy development related to the possible establishment of a national reserve of power transformers that support the bulk power grid.

Large power transformers are essential components of the electric grid that control the high-voltage flow of our nation's electricity. Because these transformers are essential to the function of the bulk power system, the grid is vulnerable to a coordinated attack or natural disaster impacting multiple transformers that could result in widespread and prolonged electricity outages.

NEMA recommends that the U.S. Departments of Energy and Homeland Security and the Federal Energy Regulatory Commission work with bulk power system owners/operators, utilities, manufacturers, state public utility commissions, and other stakeholders to establish a national strategy that includes regional pools of transformer equipment reserves that are strategically placed to enable the prompt restoration of the bulk power system in the event of a natural disaster, physical attack, cyberattack, or other unforeseen emergency that results in the catastrophic failure of multiple large power transformers.

If you have any questions about our comments, please contact Patrick Hughes, Director of Government Relations, at 703-841-3205 or patrick.hughes@nema.org.

Sincerely,

Kyle Pitsor

Kyle Pitsor
Vice President, Government Relations

Comments by the Power Transformer Section of the National Electrical Manufacturers Association[1] on the Department of Energy's "National Power Transformer Reserve" Request for Information

August 24, 2015

1. Program Need
Is there a need for a National Power Transformer Reserve? How would such a reserve affect the reliability and resiliency of the North American bulk power system? Are there alternatives to a power transformer reserve program that can help ensure the reliability, resiliency, and recovery of the bulk power system? Is there a need for a nationally-maintained inventory of large power transformers?

Yes, there is a need for a national power transformer reserve.

NEMA recommends that the U.S. Departments of Energy and Homeland Security and the Federal Energy Regulatory Commission work with bulk power system owners/operators, utilities, manufacturers, state public utility commissions, and other stakeholders to establish a national strategy that includes regional pools of transformer equipment reserves that are strategically placed to enable the prompt restoration of the bulk power system in the event of a natural disaster, physical attack, cyberattack, or other unforeseen emergency that results in the catastrophic failure of multiple large power transformers.

Background

Large power transformers (LPTs) are large, expensive, custom-designed, and essential components of the electric grid. They control the high-voltage flow of our nation's electricity by either increasing the voltage of electricity from generation sources for long-distance transmission ("step-up") or decreasing the voltage of electricity close to the customer for end use ("step-down"). Because LPTs are essential to the function of the U.S. electric grid, the grid is vulnerable to a coordinated attack on multiple transformers that could result in widespread and prolonged electricity outages.

LPTs are located throughout the country's electric transmission and distribution substations, usually exposed to the elements, and are at-risk from extreme weather events. Recently, LPTs have received much attention for their vulnerability to criminal or terrorist attack, such as the 2013 rifle assault on a California transmission substation. Geomagnetic disturbances (GMD) and electromagnetic pulse (EMP) are also of concern.

[1] The members of the NEMA Power Transformer Section include: ABB, CG Power Systems USA, Cooper Power Systems by Eaton, Federal Pacific, Hammond Power Solutions, MGM Transformer Company, ONYX Power Inc., Power Quality International LLC, Prolec GE, Schneider Electric, Siemens, SPX Transformer Solutions, and WEG Electric Corp.

Because the transmission grid is designed with redundant systems to increase stability, the failure of a single LPT is not likely to result in a major power disturbance. However, the unprecedented failure of multiple LPTs could lead to a significant widespread outage. Therefore, NEMA sees the need to address the vulnerability of the U.S. electric grid through a coordinated, comprehensive solution that provides national coverage of regionally located transformers that can be quickly deployed to any bulk power system owner/operator in the event of an emergency.

If multiple LPTs were to be disabled by any of the causes mentioned above, our nation would currently have limited ability to rapidly replace them and restore the flow of power. This is due to the long lead-times for the production, transportation, and installation of LPTs. Complicating factors include their size, weight, degree of customization, and considerable expense.

The Problem: Transformer Replacement Cycle Duration

The confluence of multiple challenges—production, transportation, and installation—creates a situation where the United States is unprepared for an unprecedented outage of multiple transformers. A single transformer outage can be addressed through existing industry programs and practices, but if multiple transformers need to be replaced, there are significant production, transportation, and installation constraints that will prevent the rapid replacement of compromised transformers.

A Typical Transformer Order Cycle

Customer specifications:	1 month
Request for quote:	1 month
Design:	3 months
Material procurement:	3 months
Manufacture:	2 months
Ship:	1 month
Commission:	1 month
Total:	**12 months**

Production: LPTs cost millions of dollars and involve production lead times ranging from 12-24 months. Periodic material and component shortages can add to production delays. Specific components to LPTs include: bushings; load tap changers; specialized (and mostly imported) electrical steel; uniquely formed copper (no two transformer designs use the same copper wire); and high-voltage insulation. Bushings are generally produced out of porcelain for the external insulator, and as the porcelain is no longer manufactured in North America, it alone can have 26-40 week lead time. Periodic disruptions in the import of electrical steel have also adversely affected production schedules.

Very few LPTs have the same design. In fact, with 70 percent of the LPTs installed in the U.S. being more than 25 years old, their engineering designs are outdated for both manufacturing and current technology. When replacing older units, manufacturers must generate new electrical and mechanical designs, which together add a minimum of 3-4 months to the replacement time. The electrical design alone can be hundreds of hours, while the mechanical design can take between 1,000-2,000 hours.

Transportation: Once manufactured, the transportation and delivery of these large, ultra-heavy units pose challenges to their replacement. Depending on power requirements which dictate unit size, LPTs generally weigh between 100 and 400 tons, and sometimes more. Their size and weight often require delivery by specialized train cars and trucks with exacting site access plans. These specialized train cars and trucks have limited availability in North America. In addition, with many existing LPTs in place for more than 40 years, the routes of access once available to them have since been de-rated or even removed, leaving some substations and LPTs virtually landlocked and inaccessible for replacement.

Installation: Installing a transformer is a major event. Since a LPT must be disassembled to ship and then reassembled on site, specialized knowledge, skills, and equipment are necessary to complete the final installation. Matching electrical parameters from one transformer to the next is not enough. Physical parameters and footprint constraints must also be considered in order to fit the unit into its designated location. As the layouts of substations are rarely alike, unit cooling, wiring interconnects to control systems, and security needs all play a role in unit size, design, and placement.

Finally, issues involving the structural integrity of the concrete pads supporting older transformers are also common. When pad replacement is required prior to installation of a new transformer unit, further time and complexity is added to the installation.

It is important to recognize that even new generally interoperable and rapidly deployable transformers only reduce the time it takes to transport and energize a LPT; the manufacture of the units still take months. Should an event occur that requires a replacement transformer, utilities would still face a long delay if a replacement unit is not already built. Having appropriate reserves of LPTs, located at strategic points around the country, would fill this gap and complement existing industry programs.

Existing Programs

While the establishment of a reserve capability provides unique benefits that cannot be achieved through any other means, it is by no means the only measure needed to ensure reliability, resiliency, and recovery of the bulk power system. The National Electrical Manufacturers Association (NEMA) recognizes that there are existing programs that seek to address these problems. Industry and government have taken steps to both prevent damage (hardening) to critical infrastructure and to aid recovery (resiliency) in the event that damage occurs.

Manufacturers: Manufacturers are addressing both hardening and resiliency. NEMA members are actively involved in industry efforts to develop standards and best practices for hardening transformers, including an effort at the Institute of Electrical and Electronics Engineers (IEEE) to study the impacts of geomagnetically induced currents that, if large enough, could lead to voltage instability and potentially even blackouts.

Manufacturers are producing hardened LPTs and connected components such as dry bushings as well as fully enclosed substations. Anti-ballistic armor is also an option. On the resiliency side, smart grid technologies can mitigate the impact of a disabled LPT on the surrounding grid.

In addition to individual manufacturers' efforts, the industry has come together under the auspices of NEMA to develop joint industry recommendations for how to reduce the time it takes to replace compromised transformers.

Edison Electric Institute (EEI): EEI's Spare Transformer Equipment Program (STEP) is a voluntary program whereby participating utilities are contractually bound to sell their spare transformers to any other participating utility that suffers a "triggering event." A triggering event is defined as an act of terrorism that destroys or disables one or more substations and results in a declared state of emergency by the President of the United States. Due to the diversity of voltages and impedances on the U.S. electric grid, the program's usefulness relies on the match between the spares available and the system that experiences a failure. Because STEP is limited to acts of terrorism, it fails to account for the other ways in which a transformer could be damaged, including natural disasters, geomagnetic disturbance, or improper grid operation.

Bulk Power System Owners/Operators: Bulk power system owners/operators have taken steps to boost their own level of resiliency. In fact, many bulk power system owners/operators maintain their own spares (though they are often located alongside the energized units at the substation, subjecting them to the same threats that face the energized units). Utilities are also investing in smart grid technologies that can mitigate the impact of a disabled LPT on its surrounding grid. Some utilities have mutual assistance agreements with other utilities that may include sharing of LPTs. Unfortunately, not every large power transformer owner/operator has adequate access to spare transformers, which is why it is important to have a comprehensive, coordinated solution to this problem.

Private-Sector Transformer Reserve Programs: While participants in private-sector transformer reserve programs like Grid Assurance LLC, WattStock LLC, and Pooled Inventory Management (PIM) may be adequately prepared for a disaster, their contribution to nationwide resilience is only as widespread as their participants' footprints. These programs would not cover non-participating bulk power system owners/operators in the event of an emergency. Natural and man-made disasters do not observe service territory boundaries, and therefore it is important that a nationwide solution include all large power transformers owners and operators. Steps should be taken to reduce bureaucratic hurdles that could impede the effectiveness of such transformer reserves in an emergency.

> *Grid Assurance LLC:* Recently, eight utilities banded together to launch Grid Assurance LLC, a user-fee-financed private entity that would acquire, store, maintain, and facilitate the sharing of transformers and

other critical grid equipment between those eight utilities in the event of an emergency.

WattStock LLC: Similar to Grid Assurance LLC, WattStock LLC is a private-sector company that maintains a supply of LPTs and provides them to customers through subscription fees, leases, or sale agreements. WattStock LLC helps those companies that participate prepare for a potential LPT outage, but a nationwide solution is still needed to ensure that spare equipment is accessible to all large power transformers owners and operators, not just those subscribing to a voluntary service.

Pooled Inventory Management (PIM): Created in 1980, the Pooled Inventory Management (PIM) program primarily serves the U.S. nuclear power industry by procuring and storing long lead-time equipment (including transformers) that can be rapidly deployed in the event of a component failure.[2] While an important and enduring program, PIM's narrow focus on the nuclear industry and its membership-based structure limit its ability to serve as a nationwide backstop in the event of an unprecedented number of simultaneous transformer outages.

North American Electric Reliability Corporation (NERC): NERC's Spare Equipment Database is a voluntary and confidential information sharing resource to connect its approximately 1,900 participants with those with an immediate technology need (due to a high-impact, low-frequency event) with potential suppliers of spare equipment. While the program can be used in a broader range of transformer outage scenarios than the EEI STEP program, its services are limited to participants, transformers are shared between bulk power system owners/operators on a voluntary basis only, and it does not provide nationwide coverage.

In addition to the NERC Spare Equipment Database, NERC members are required to meet minimum reliability standards. A transformer reserve would be used for contingencies outside of those prerequisite NERC mandates.

Federal Energy Regulatory Commission (FERC): In November 2014, FERC, through Order 802, approved a physical security reliability standard (CIP-014-1) for critical transmission assets. The standard requires owners and operators to identify their critical assets, evaluate physical security threats to and vulnerabilities of these assets, and develop and implement security plans. In June 2014, FERC, through Order 797, approved a reliability standard (EOP-010-1) governing how owners and operators respond to geomagnetic disturbances.

Department of Energy (DOE): DOE has researched and evaluated LPT issues for many years, the hallmark of which has been its 2014 *Large Power Transformers and the U.S. Electric Grid* report.

[2] http://www.pooledinventorymanagement.com/(S(tttvhlns30hfosyguacmvf55))/public/progdesc.aspx

Department of Homeland Security (DHS): The DHS Science and Technology Directorate, working together with the Department of Energy, led the development of a prototype recovery transformer which is lighter, smaller, easier to transport, quicker to install, and compatible with a greater variety of electric systems than a conventional LPT. DHS reported its findings and implications for a spare transformer program in its final report [3]

Congress: Congress amended Title I of the *Defense Production Act* (DPA) of 1950 (P.L. 81-774, 50 U.S.C. App. §2061 et seq.) in 1975 as part of the *Energy Policy and Conservation Act* to include several provisions related to domestic energy.[4] Section 101(c) of the *Defense Production Act* authorizes the President to allocate and prioritize contracts for materials, equipment, and services to maximize domestic energy supplies in certain circumstances. LPTs would be included under this provision. More recently, on July 22, 2015, the House Energy and Commerce Committee Subcommittee on Energy and Power unanimously passed a draft "Committee Print" version of comprehensive energy legislation that would, if enacted, direct the Department of Energy to develop a plan to establish a strategic reserve of large power transformers.[5]

Despite near universal recognition of the risks facing LPTs and limited programs like the Spare Transformer Equipment Program, the NERC Spare Equipment Database, Pooled Inventory Management, WattStock LLC, and Grid Assurance LLC, no comprehensive strategy exists for dealing with the potential catastrophic loss of such equipment as a result of high-impact, low-frequency events (e.g., physical attack, cyberattack, natural disasters, geomagnetic disturbance, electromagnetic pulse, etc.). The steps that have been taken by many stakeholders are indeed valuable and do not need to be duplicated; yet without a comprehensive strategy, NEMA is concerned that the industry is still not adequately prepared for the full range of contingencies. Therefore, we support a coordinated, comprehensive solution that provides national coverage of strategic spare transformers in the event of an emergency.

NEMA recommends that the U.S. Departments of Energy and Homeland Security and the Federal Energy Regulatory Commission work with bulk power system owners/operators, utilities, manufacturers, state public utility commissions, and other stakeholders to establish a national strategy that includes regional pools of transformer equipment reserves that are strategically placed to enable the prompt restoration of the bulk power system in the event of a natural disaster, physical attack, cyberattack, or other unforeseen emergency that results in the catastrophic failure of multiple large power transformers.

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[3] http://www.dhs.gov/sites/default/files/publications/RecX%20-%20Emergency%20Spare%20Transformer%20Strategy-508.pdf
[4] http://www.gpo.gov/fdsys/pkg/STATUTE-89/pdf/STATUTE-89-Pg871.pdf
[5] http://energycommerce.house.gov/sites/republicans.energycommerce.house.gov/files/114/07-20-15%20EP%20Subcomm%20Draft.pdf

Given the complexities of the electric system—its sheer size, the large number of owners and operators, uneven technical specifications, varying business models, and a multitude of regulatory bodies—precisely how such a strategic transformer reserve should be designed and operated is a topic that warrants detailed analysis and close consideration by all stakeholders, including the federal government. Government resources and expertise, in conjunction with participation from bulk power system owners/operators, manufacturers, public utility commissions, and other industry stakeholders, would be invaluable in ensuring that a national strategy underpins industry's response to this issue. NEMA thanks the U.S. Department of Energy for issuing this important request for information, and we look forward to continuing to work with DOE to further examine this important topic.

2. Power Transformer Criteria
What types and sizes of power transformers should be considered for inclusion in a transformer reserve program versus operational spare capacity? What are the design considerations for replacement transformers to support the bulk power system?

Transformer Criteria

When considering which transformers to include in a reserve program, factors to consider include: voltage and capacity (kV/MVA) ratings, variable taps/multi-ports, flexible fit, ease of transport, rapid installation and energization capabilities, and the number of units required.

> *Voltage and Capacity Ratings:* In an operational program bulk power system owners/operators may maintain a spare unit for each kV/MVA (kilovolt/megavolt ampere) class, from the very highest kV/MVA down to much lower kV/MVA.
>
> By contrast, a strategic transformer reserve would be directed at large power transformers that form the backbone of the bulk power system. However, a detailed analysis will need to be conducted to identify the types of spare transformers that need to be included in a transformer reserve.
>
> *Flexibility to fit multiple systems:* In the case of operational spares, because replacements are intended to be permanent, bulk power system owners/operators individualize transformer designs to maximize energy efficiency and otherwise optimize the design for each particular unit and location.
>
> By contrast, a strategic transformer reserve should provide the maximum flexibility in form, function, and fit to ensure the broadest capability with the minimum number of units in reserve. This would limit the number of kV/MVA classes but provide variable taps, multi-ports, and modular system capabilities, as well as possible self-padded units.

Ease of transport and installation: Operational spares are often located on-site where transportability is a non-issue. Or, if a transformer is showing signs of impending failure, utilities often have time to develop a transportation plan for an off-site replacement transformer, even for a traditional, extra-large, extra-heavy unit.

However, in an emergency a transformer in reserve does no good if it cannot be quickly delivered to where it is needed. An effective strategic reserve would place spare units in multiple centralized locations accessible to multiple substations. Since the units are not on site, they must be quickly transportable and designed for rapid installation and energization.

Number of units: An operational program may need just a few replacement units of each transformer class, since failure of multiple units at the same time is rare in normal operation. But because a strategic transformer reserve is intended to respond to the concurrent loss of multiple LPTs, the program would require the regional stockpiling of a pool of replacements for the most common and most critical transformer types.

3. Ownership and Economics
What would be an appropriate structure for procuring and inventorying power transformers? How, and by whom, should a program of this type be administered? How would a transformer reserve be funded?

We take no position regarding the structure for procuring, inventorying, funding, and administration of a transformer reserve at this time. As the process moves forward, NEMA looks forward to further discussion with industry stakeholders and the Department of Energy on these questions.

4. Technical Considerations
Is it technically feasible to develop a reserve of large power transformers when most are custom engineered? Is additional research and development (R&D) necessary to develop suitable replacement transformers that can be rapidly deployed from inventory in the event of an emergency?

Interoperable Design

While large power transformers are typically custom engineered for their service location and specific owner/operator requirements, there is a proven potential to establish a group of designs based on matching technical parameters which are critical for LPTs functioning on the network (voltages and impedance). This, in combination with vulnerability and risk assessment, would lead to a manageable number of designs.

A reserve should consider design features which will support rapid transportation, plug-and-play and interoperability over the custom design needed to optimize transformer operation. Therefore, some degree of compromise will be needed to minimize the number of required designs.

One of the many possible solutions is a rapid recovery transformer, similar to the one designed and built in partnership with the U.S. Department of Homeland Security, the Electric Power Research Institute, and CenterPoint. This transformer has engineered designs and materials to improve interoperability with the majority of LPTs on the North American grid, and a reduced size and weight that permit rapid deployment and energization.

Existing Technologies

The technologies needed to build smaller transformers have been in use for many years in mobile, railway, and industrial units. In combination with modern engineering modeling tools (e.g., thermal, transient, and 3D dielectric and magnetic), this gives the industry confidence that a fleet of recovery units can be specified and built.

The research on power flow at critical inter-tie network points in combination with a range of expected transformer parameters (voltages and impedance) may be required if not already done as part of the co-operation between bulk power system owners/operators and regulatory commissions.

5. Procurement and Management

How should procurement, maintenance and management of the reserve power transformers be conducted? For example, should manufacturers be pre-qualified, and if so, according to what criteria?

NEMA does not take a position at this time on how the program should deal with procurement of transformers, nor do we take a position at this time on how the reserve should be maintained and managed.

6. Supply Chain

What are the critical supply chain components for the manufacture and delivery of large power transformers (e.g., electrical steel, copper, silicone, high voltage bushings, etc.)? Are there shortages or other considerations that could necessitate using the Defense Production Act Priority Ratings to ensure sufficient parts are available in a time of need? Are there related skilled workforce issues?

Supply Chain Constraints

Transformers cost millions of dollars, with a substantial amount of that cost invested in materials. While a considerable number of trained manufacturing and assembly personnel are available to produce transformers, both materials and facility limitations exist.

There are specialized components unique to large power transformers which include major sub-assemblies such as bushings; both de-energized and on-load tap changers; oil preservation systems; and cooling systems (radiators and forced oil/air coolers). Additionally, specialized, and mostly imported, electrical steel is needed to construct the magnetic circuit of the transformer. Uniquely formed and insulated copper is needed as no two transformer designs use the same copper wire. High-voltage insulation in the form of pressboard is also required.

> *Bushings:* In terms of bushings, most are produced using porcelain as the external insulator. The higher voltage bushings are very large and their porcelain is no longer manufactured in North America. This becomes a major issue as the porcelain alone can have a 26 to 40 week (or more) lead time. Castings and machined metals (typically aluminum and copper) are available domestically and typically limited by casting/machining processes.
>
> *Tap Changers:* For on-load tap changers, the lower voltage tap changers are manufactured in North America. However, most high-voltage systems are sourced from outside the continent. The materials for some of these are specialized fiberglass, and in some cases vacuum bottles.
>
> *Cooling Systems:* Cooling systems are manufactured in North America and basic materials are available. The same is true for oil preservation systems, with the exception of the oil/air separation membranes.
>
> *Electrical Steel:* The greatest concern is for the supply of specialized electrical steel. Sources to cut the rolls of steel into the specific shapes required for transformer production are available in North America, but the rolls of steel are often imported. In the past, there have been periodic disruptions in the import of electrical steel that have adversely affected production schedules.

7. Manufacturing
Is there adequate manufacturing capacity to support a transformer reserve program? What is the lead time for engineering, manufacture, and delivery of large power transformers? Are there approaches that could help to speed manufacture and delivery of large power transformers?

Manufacturing Capabilities

NEMA believes there is sufficient manufacturing capacity in North America to support a transformer reserve.

Manufacturing of large power transformers takes place in environmentally controlled facilities. These factories must have the ability to lift very heavy weights. The manufacturing process is typically performed in parallel paths to minimize production time. Specialized equipment to dry and impregnate the insulation material is also used to minimize manufacturing time. During the grid build up in the mid-20th Century, production capacity was significantly greater than that in place today.

Many transformer facilities are operating at or near capacity. Expansions of manufacturing facilities are a possibility depending on the outlook for market demand.

Manufacturing capacity does not solely depend on facilities. Skilled workers with unique training must be used in the critical processes of transformer assembly. These workers typically take years to develop, and current manufacturing facilities are staffed with a workforce that is able to meet the current demand for transformers. Some service organizations also rely on the same skilled workers to perform transformer reassembly at the generating plant or substation, which could be shifted in part to transformer manufacturing. However, those service organizations would need similarly skilled workers, so workforce development programs would be needed to complete a capacity increase effort.

Since typical large power transformers have a unique design to optimize power flow on the grid, a significant amount of time is devoted to the design process. This time requirement to design a unique large power transformer can take up to 3-4 months. The electrical design alone can be hundreds of hours, and the mechanical design can take between 1,000-2,000 hours.

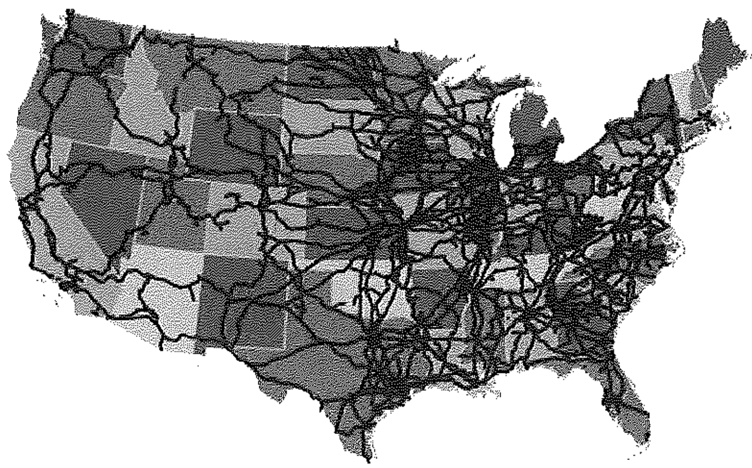
In the event of an emergency, if a current design is available, the design time can be saved by simply producing a duplicate transformer. Since many of the existing critical transformers are many years (if not decades) old, design work must take place to utilize current materials. Support for updating the designs for the most critical transformers would have the opportunity of saving the electrical and mechanical design time and moving straight to materials procurement. Transformers of the same design could thus be manufactured for a reserve, saving both the design cost and time. Production of duplicate transformers would also be accelerated, since the workforce would be performing repeat tasks instead of dealing with the current flow of unique designs.

8. Transport and Deployment
What specialized transport infrastructure would be necessary to ship large power transformers from manufacturing site to storage locations, and from storage locations to field site in the event of an emergency? What should be the number and location of transformer storage sites? What are feasible delivery times for LPTs that reside in a reserve to an affected site?

Transportation and Delivery

The transportation and delivery of these large, ultra-heavy units (which range from 100 to 400 tons) from the manufacturing site to storage locations will require the use of specialized heavy duty depressed-center rail cars. These specialized rail cars have limited availability in North America; therefore, a certain quantity would need to be acquired and made available to the manufacturer.

The storage location should be rail-served with the temporary pad strategically placed alongside the rail tracks so that the unit can be off-loaded and eventually reloaded by a hauler/rigger utilizing a jack and slide method.



Map of Class I Railroads in the United States
Source: Association of American Railroads

The same fleet of rail cars would serve for the transport from the storage location to the designated field site. Agreements would need to be in place with the railroads, hauler/riggers and departments of transportation for emergency cases.

In order to assure quick and easy access, there could be one storage site located at each of the Class I railroads, which would cover the geographical regions of the United States:[6]

- BNSF Railway
- Canadian National Railway Company
- Canadian Pacific Railway
- CSX Corporation
- Kansas City Southern Railway Company
- Norfolk Southern Railway
- Union Pacific Railroad

In the case of an emergency, a feasible delivery time for LPTs from the storage location to site would be one to two weeks depending on the complexity and distance of the move from the nearest rail siding to the affected site.

Note: The routes of access once available to many sites have since been de-rated or even removed, leaving some substations and LPTs virtually landlocked and inaccessible for replacement.

[6] http://www.freightrailworks.org/network/class-i/

9. Field Engineering and Installation
Are there adequate domestic engineering and installation resources available throughout the United States to install multiple bulk power transformers simultaneously? What additional resources would be necessary?

Installation Considerations

Transformers in long-term storage in the strategic reserve should be stored filled with oil to minimize the processing time in the field. If stored dry, extensive re-impregnation with oil is required that can add weeks to the assembly process. Preparing the transformer for shipment, transportation, and reassembly in the field is a major event. Since a large power transformer must be disassembled to ship and then reassembled on site, specialized knowledge, skills, and equipment are necessary to complete the final installation of a LPT. All units must be wired back to power and a control system. Therefore, the location of the electrical interconnection is critical in placing the new or replacement unit within the substation.

Transformer service providers and many bulk power system owners/operators have personnel trained with the special skills necessary to assemble and process transformers. The special equipment necessary to process a transformer is limited. A large sudden demand would stress those assets. Preparation and use of a familiar design would help to minimize the time required to install transformers. Equipment and trained workers would be critical in the deployment of a large number of transformers.

It should be noted that matching electrical parameters from one transformer to the next is not enough. Physical parameters must also be met in order to fit the unit into its designated location. The layouts of different substations are rarely alike. When setting a new transformer in place, there must be adequate room for the cooling configuration on the unit.

Issues involving the structural integrity of the concrete pads supporting older transformers are also common. When pad replacement is required prior to installation of a new transformer unit, further time and complexity is added to the installation.

10. Criteria for Deploying Transformers
What criteria should be used for activating and deploying transformers from the reserve? How would deployment be funded?

Deployment in a Comprehensive and Flexible Range of Scenarios

Transformers can be compromised in a number of different ways—natural disasters, physical attacks, cyberattacks, geomagnetic disturbances, electromagnetic pulses, etc.—and therefore a transformer reserve program should be flexible enough to provide spare transformers and other critical equipment to bulk power system owners/operators regardless of the triggering event. Furthermore, the aforementioned emergencies will not observe service territory boundaries, so a transformer reserve solution must be nationwide in scope. A flexible and comprehensive transformer reserve would address critical gaps in our nation's preparedness to improve the resilience of the electric grid to man-made attacks, accidents, and natural disasters, and therefore a nationwide solution is needed to deploy transformers under a broad range of scenarios, some of which may not yet have been hypothesized.

Funding

At this time, NEMA takes no position on how deployment of large power transformers would be funded, but we would like to reiterate that the program should be nationwide in scope, open to any bulk power system owner/operator that owns or operates a large power transformer or other critical grid equipment, and should have regional equipment reserves to facilitate the rapid deployment of large power transformers.

11. Additional Comments
Are there additional concerns regarding a National Power Transformer Reserve Program that need to be considered?

Coordination with Stakeholders

Developing a useful transformer reserve requires participation from all stakeholders—bulk power system owners/operators, utilities, manufacturers, industry stakeholders, public utility commissions, governmental and non-governmental officials, and those involved in emergency planning.

A transformer reserve should be coordinated with existing state emergency planners that can provide support during emergencies. This would extend to state public utility commissions.

Since the bulk power system extends beyond national boundaries, coordination for emergency deployment should also extend to Canada and Mexico, which have historically provided support during major emergencies (e.g., Hurricane Katrina and Superstorm Sandy).