To: Department of Energy

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Attn: Alice Lippert, Office of Electricity Delivery and Energy Reliability

Subject: Transformer Reserve

Response to Request for Information, FR Doc No: 2015-16784

1) **Program Need**
   a) **Is there a need for a National Power Transformer Reserve (or not)?**
   There does not appear to be sufficient information available within the public domain to provide a definitive answer to this question. Therefore, a *"sic et non"* set of responses are provided instead in an attempt to provide some useful insight.
      i) *"Sic"*
         (1) Previously established transformer reserve programs appear to be inadequate to fulfill the needs of utilities and others in the industry, otherwise, the recent announcements by Grid Assurance LLC and Wattstock LLC to establish new programs would not have found fertile markets.
         (2) Existing programs such as PIM, STEP and SED, while in operation for many years have been practically unused by members owing to what has been commented by others as having extremely high trigger levels (Presidentially declared emergency) and of little practical value due to lack of participation.
         (3) Industry cannot be expected to invest large sums on Large Power Transformers (LPT's), especially of an emergency design given that their use might only occur during a High Impact Low Frequency (HILF) event and given that the Investor Owned Utility (IOU) industry is limited to rate increases approved by individual state Public Utility Commissions (PUC's) from which they must return a minimum Rate of Return (ROI) to their investors.
         (4) Investments to prepare for a HILF event must be predicated on a relatively well known probability of a HILF event and the number of transformers which would fail under these circumstances. A survey of insurance and transformer industry papers indicate that there is insufficient data available for IOU's to invest with a predictable ROI. The need is particularly acute for smaller utilities, both public and IOU, which generally have fewer resources and whose customers suffer disproportionately during major outages.
      ii) *"Non"*
         (1) Utilities are mandated via FERC and regulated via NERC to provide reliable service to their customers, including mandatory restoration. In

exchange, utilities are granted a monopoly on the transmission and selling of electricity to their customers. Direct investment from Federal resources is essentially a direct subsidy to utilities and only serves as a disincentive for utilities to replace an already over-aged fleet of LPT's (cf. Stafford Act).

(2) Since NERC currently has a spare transformer program and NERC is subject to FERC mandates, it might be more effective for FERC to request that NERC modify its existing programs to increase their effectiveness in light of new requirements for resiliency and reliability.

(3) Outage statistics show no indication that major outages have been caused by the direct failure of one or more LPT's. Examples of major outages such as the Hydro Quebec (1989), Katrina (2005) and Sandy (2012) were not caused by the failure of LPT's. Most large outages are caused by the cascading effect of smaller outages, often associated with the loss of one or more transmission lines for reasons other than the loss of an LPT and not predicted within the N-1 criteria established by NERC. The 2003 Northeast outage is such an example where line overloading, lack of line maintenance and poor control coordination to prevent cascading faults and recover from them led to disastrous results. Having a reserve of LPT's for the transmission system would have done little or nothing to prevent this and other historical outages.

b) How would such a reserve affect the reliability and resiliency of the North American bulk power system (or not)?

i) "Sic"

(1) A strategic reserve of LPT's, properly designed, would allow all utilities to improve their general reliability performance since they could readily replace a failed LPT in a much shorter time span than locating, repairing or purchasing a new or used replacement appropriate to their needs. Reserve units could be used in both a HILF and isolated failure scenario.

(2) Reliability is also enhanced since the use of a less optimal replacement transformer such as a used or borrowed LPT, would limit line loading and possibly force other lines to carry additional load, leading to an increased risk for a large or cascading outage. Otherwise, loads may need to be reduced with their consequent economic losses to the utilities and their customers.

(3) Resiliency would be increased, at least theoretically, since the pool of available LPT's would be large enough to cover a greater range of contingencies. including a greater chance to recover from a HILF scenario, such as EMP, GMD/GIC and coordinated attacks.

ii) "Non"

(1) Having a National Power Transformer reserve does nothing to improve the resiliency and reliability, since it has yet to be proven historically (or adequately modeled for future risks), that HILF events or their recovery would have been enhanced. The only method to prove otherwise is to

examine the responses of utilities to HILF events where their recovery was hampered from a lack of transformers.

(2) Reliability might be enhanced, but only because a reserve would provide newer LPT's on the the system and generally lower the average age of LPT's as they are replaced on a regular basis. Note that there is a strong correlation between the age of LPT's and their failure rate. However, as previously mentioned, the continuous replacement of LPT's is the responsibility of utilities for which they should already be adequately compensated. Newer LPT's tend to have a lower in-service failure rate, so lowering the average age of the installed base reduces the risk of failure, which in turn reduces the risk of a cascading outage.

(3) One of the major challenges during recovery from the 2003 North East blackout was to generate enough electricity within the region to re-energize the lines, given that all of the connections with other regions had been severed. The region was lacking in generation assets required for a black start to re-energize the lines and re-synchronize generators. As a result, generation plants that had been moth-balled or relegated to back-up for many years had to be put into operation with unpredictable results. If Generator Step-Up transformers (GSU'S) or plant auxiliary transformers (UAT's and SST's) had been damaged during the outage from transients, then recovery could have been far more difficult. A fleet of spare LPT's for the bulk transmission system, composed exclusively of autotransformers, would have had little or no impact on the speed of recovery.

c) Are there alternatives to a power transformer reserve program that can help ensure the reliability, resiliency, and recovery of the bulk power system?

i) "Sic"

(1) Alternatives do exist. The bulk power system in North America is broken down into 8 regions (4 for interconnections) for various reasons of control and reliability. Since each region faces differing sets of circumstances, it may be more appropriate that each region establish its own program.

(2) Programs such as PIM, STEP and SED already exist, so it is a question to determine the effectiveness of these programs and what changes, if any, are required to improve them.

(3) Since NERC has the mandate for ensuring reliability of the bulk power system, then they should also have the mandate to create, oversee or validate effective reserve programs.

(4) Private industry has already shown significant interest in developing reserve programs for both transmission and generation (i.e. Grid Assurance LLC and Wattstock LLC). The business models of both are dependent on membership dues from participating utilities and power producers.

(5) Individual utilities participating in the bulk power system should be required to analyze and report their existing preparedness based on some standard reference or score. A minimum score or preparedness should be

maintained by each utility and additional spare LPT's or a guarantee of access to them, be obtained at their cost, presumably paid for by compensation through the rate base guaranteed by the individual PUC's or through a special federal fund if deemed necessary in the case of HILF events which cannot be adequately foreseen (e.g. coordinated attack).

ii) *"Non"*

(1) A number of alternatives either exist or are being proposed. However, if the these programs do not or will not cover the necessary needs to achieve the desired level of resiliency and reliability, or if the required private investment does not provide a minimally acceptable ROI, then there is probably no feasible alternative to a national program backed by federal funding.

d) Is there a need for a nationally-maintained inventory of large power transformers?

The first part of the question refers to a reserve while the last to an inventory. Whether or not a reserve and an inventory are the same, the previous responses apply to both. Of course, the physical reserve or inventory can be established in a number of ways; physically centralized, dispersed or installed and in operation throughout the bulk power system, or any combination thereof.

2) Power Transformer Criteria

a) What types and sizes of power transformers should be considered for inclusion in a transformer reserve program versus operational spare capacity?

The bulk power system already has significant operational reserve capacity. However, the system capacity is not simply the sum of the system load divided by the sum of the transformer nameplate capacity. Capacity has to be calculated in light of the load conditions which are very dynamic and based on a wide variety of operating circumstances, including HILF events. Only advanced load flow analysis can give a clear indication even under normal conditions. Special models for HILF events would have to be developed to compliment load flow under normal conditions.

In addition to load flow, very sophisticated failure models need to be developed for LPT's. Currently available statistics and historical analysis of LPT's would need to be developed into predictive models that could be applied to any specific transformer and which take into account the age, manufacture, design, operational history and condition of each LPT, including its major subcomponents. Without such sophisticated analysis and predictive models, only the most general estimates based on an average failure rate applied to the range of installed LPT's can be used. However, such an analysis gives no priority to critical nodes within the bulk power system.

b) What are the design considerations for replacement transformers to support the bulk power system?

There are a number of different design considerations that might apply. One of the primary ones is the use of single phase units versus three phase units. Originally, single phase units were used extensively for LPT's because the failure rates of transformers were historically higher then and single phase units reduced the risk of losing and entire three phase bank. It was also a common practice to purchase a spare single phase LPT for one or more three phase banks for reliability. This practice was also popular because transformers were much larger and heavier than modern ones and the transport system less developed, meaning that single phase LPT's were much easier to transport. As transformer technology and transport systems improved, LPT's became more reliable and smaller, making three phase LPT's more economical. The number of single phase LPT's has steadily declined as a percentage of all LPT's over the last three generations, although there are still viable applications. They are still used extensively in other parts of the world because of their ease of transport. A return to an increased use of single phase LPT's, while representing a cost increase, does improve overall reliability and resilience. As a rule of thumb, a single phase LPT costs approximately 2/3 of a three phase equivalent.

Another approach to increasing reliability and resilience is the extensive paralleling of transformers, each operating under 50% of their nameplate capacity. Again, this is already a common practice by many utilities with the idea that the incremental cost of increasing the increasing LPT capacity (MVA) decreases with total capacity. Many utilities embrace this approach because it allows for long term expansion of system capacity and confers the additional benefit of easily performing maintenance while giving a degree of resilience and reliability in the case of transformer failure.

Most large utilities try to standardize their designs as much as possible and maintain a certain number of compatible LPT's as spares. These spares are not necessarily designed as emergency spares, but rather the same or similar to those installed. Typically, older LPT's are retired from active use and placed in storage near the end of their life until it has been determined that they are no longer needed and are then sold or scrapped. While LPT's are all conform to the same standards like IEEE, many utilities purchase LPT's according to their specific specifications with differing voltages, impedances, winding configurations and the like, making it difficult to extend this practice between utilities.

LPT's designed specifically as emergency spares use a combination of technologies, many of which have been employed for many years, to achieve a specific set of design criteria, namely:

- light weight for ease of transport (normally single phase)
- small shipping dimensions for ease of transport (normally single phase)
- ease of installation and commissioning
- multiple connections (HV or LV or both) for flexibility of operation
- multiple or extended taps for flexibility of operation

Achieving these priorities means sacrificing the typical ones for standard LPT's, specifically,

- lowest evaluated lifetime cost (first cost plus cost of lifetime losses)
- standard temperature rise for long life
- three phase designs to minimize substation space

3) Ownership and Economics

a) What would be an appropriate structure for procuring and inventorying power transformers?

Assuming that the decision of answer to the first question is that there is a need for a National Power Transformer Reserve, then procurement would be dictated by issues of ownership, participation and funding. Procurement would be determined in accordance with the technical requirements of participants and the difference between the existing operational spare capacity and the targeted resiliency and reliability under anticipated conditions, including HILF events. Inventorying would be similar and based on the optimal location for the likely location for emergency use, taking into account transit time, logistics during a major event and security of the storage facility.

b) How, and by whom, should a program of this type be administered?

Administration is related to the procurement, ownership and funding of the reserve. Administration should not be completely separated from ownership and funding. It could be a shared function among owners and those funding the program or to a third party responsible to them by agreement.

c) How would a transformer reserve be funded?

Funding a reserve program presents challenges. The bulk electric power system is primarily built, owned and operated by IOU's with self-regulation via NERC under supervision by FERC. Since most IOU's obtain an ROI on investment, it would be controversial if a National Reserve Program was funded from government sources without any input from PUC's. Therefore, funding should be closely related to ownership of the LPT's and by those participating in the bulk power system that would benefit most financially from such a program.

4) Technical Considerations

a) Is it technically feasible to develop a reserve of large power transformers when most are custom engineered?

Most LPT's are custom built to user specifications with specific electrical and physical characteristics . It is possible to develop a reserve of LPT's to cover a fairly wide range of applications, albeit with some loss of optimal performance. However, fundamental to this is to first perform an appropriate analysis to determine the set of existing LPT's that may require a reserve unit (cf. Question 2a).

Once the number and characteristics of the required reserve LPT's has been determined, they need to be organized according to their general characteristics (cf. IEEE C57.12.00, etc.) and then grouped in terms of interchangeability. Grouping can be done with respect to basic criteria of:

i) Electrical fit:
Winding configurations, connections, taps, nominal voltages, tap changers, impedances, test values and impedances (IEEE C57.12.00).

ii) Physical fit:
Base dimensions, installed dimensions, physical connections, oil volume and assembled weight to ensure compatibility with existing substation arrangements.

iii) Proximity & Transport fit:
Transport weights and dimensions, shipping profiles and distance from transport nodes to determine the plausibility of transport and transport equipment and services required to move reserve transformers from their storage locations under normal and emergency conditions.

The reserve LPT's would have to be designed for the optimal number of groups, the number of reserve LPT's required and the feasibility and costs, both initial and operating, of the required designs. Optimized reserve LPT's designs would have to account for multiple connection voltages (reconnectable HV and/or LV voltages), optimized impedance for a wide MVA capacity, this while taking into considering the physical fit and transport restrictions of all of the applicable substations or generating stations.

b) 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?

The technology for LPT's originates from fundamental electrical and physical principles developed in the 19th century. Since then, the major developments have been along two dimensions: improved materials and improved design technology. Design technology began improving rapidly with the advent of digital computers. Combined, these developments have allowed a dramatic increase in nominal voltage and capacity over the last 100 years. This trend continues as LPT's are reaching 1100 kV and over 1300 MVA for extremely high capacity transmission lines (e.g. HVDC).

However, developing emergency replacement transformers that can be rapidly deployed requires a change in the design approach more than a development of new materials and technologies. Existing materials are more than adequate to currently build emergency replacement LPT's. New material and design technologies would be beneficial but not necessary. Reserve transformers have been built for a number of decades. Applying the latest design technology and materials would provide advantages over previously supplied reserve transformers.

The areas of research and development that would have the greatest impact on improvements for reserve LPT's in ranked in order of benefit conferred:

i) Solid insulation: replacement, alternatives or hybrids to existing cellulose types
ii) Liquid insulation: improvements in dielectric strength, flashpoint, thermal capacity and environmental impact
iii) Magnetic steel: improvement in flux density and losses
iv) Conductor material: improved short circuit strength, improved conductivity, lower weight materials
v) Improved analysis of LPT response to transient phenomena (e.g. EMP, GIC)
vi) Improved analysis of thermal and fluid dynamics
vii) Improved analysis of LPT failure modes to develop predictable models
viii) Improved condition assessment and analysis technology

5. Procurement and Management

a) How should procurement, maintenance and management of the reserve power transformers be conducted?

Procurement for LPT's is normally via a sealed tender process. Pre-qualified vendors are issue an RFQ or RFP for the required LPT's. If the number of LPT's is large, it may be beneficial to limit the amount awarded to a single vendor to reduce the risk of non-performance.

LTP's have special needs for long term storage (more than 6 months). They can normally be stored indoors or out but do require a substantial concrete patio or similar to support the weight. Long term storage requires that they be stored full of dielectric oil and partially assembled to prevent the ingress of moisture to the solid insulation. Otherwise, the LPT's could be rendered inadequate for emergency use, since removing the moisture adds significant time to installation. Additionally, auxiliary power needs to be connected to ensure that space heaters in control kiosks or cabinets are turned on to prevent condensation and damage to low voltage wiring. Bushings and other accessories should be stored in accordance with manufacturers recommendations, either indoors or outdoors, depending on the manufacturer and accessory. Stored LPT's require scheduled inspection and possibly maintenance to keep them in condition for immediate use.

Management of the reserve needs to consider the following:
i) storage requirements
ii) security of storage site
iii) location of storage facilities and proximity to likely use
iv) storage proximity to major transport facilities and equipment
v) availability and training of necessary crews for installation, especially if the reserve transformers use special technology
vi) Scheduling of inspections and maintenance

vii) Spare part or special tools or equipment

b) **For example, should manufacturers be pre-qualified, and if so, according to what criteria?**
LPT manufacturers should be pre-qualified based on standard industry practices. This would required audits of each potential supplier based on their manufacturing capability, technology, quality and experience with similar transformers.

6. Supply Chain

a) **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.)?**
The major components for LPT are:

i) Grain Oriented Electrical Steel (GOES)
GOES is the principal material used in the manufacture of transformer cores. Transformer cores are used to convert the electrical energy from one transformer winding into magnetic energy for transfer to another winding where it is converted back to electrical energy at a different voltage. There is no currently technology to replace its use in LPT's

GOES is a specialty type of type made with specific electrical properties specifically for transformers, motors and similar devices. Manufacturers are located around the world and market on a global basis. It is available in various grades, normally characterized in terms of its magnetic performance and losses. Not all grades are used in modern LPT's where the highest grades are required to minimize losses and weight.

The variability in global demand for all classes of transformers (low voltage, distribution and power) and other devices can result in reduced availability. Changes in trade policy or tariffs in certain regions can have significant impact on the supply and cost of GOES.

GOES has been subject to a number of anti-dumping actions both in the United States and other parts of the world (e.g. USITC Publication 4439, November 2013). US manufacturers claim that they have sufficient capacity to supply the domestic market, but it is unclear that these claims are still valid in light of the additional LPT manufacturing capacity that has been installed since 2013.

ii) Copper Conductor, including Magnet Wire (MW) and Continuously Transposed Cable (CTC)

Copper conductor for LPT's is a specially made product made from high purity annealed and electrolytically refined copper. It is specially formed and insulated, primarily with varnish and/or high grade cellulose insulating paper. Magnet wire is the simplest kind of conductor with typical only a single strand and shaped with a rectangular cross-section. When it is composed of two strands, it is normally referred to as twin conductor.

Continuously Transposed Cable (CTC) is a more sophisticated type of conductor. It is composed of the same material as MW but has many more strands in a single cable. The strands are normally enameled and the entire cable is paper insulated. The individual strands are transposed within the cable so that when a cylindrical winding is formed, each strand has the same average radial distance from the center of the winding. Transposing conductors is necessary to reduce the losses in a transformer. Before the advent of CTC. magnet wire was used and had to be laboriously transposed during the winding manufacture. This is still a normal practice for high voltage windings where currents are lower, but particularly difficult for high current windings.

More than 80% of copper is mined in only 10 countries and only about 14% within North America. Chile is the largest producer will about 30% of total global output. Other major producers are Russia, China, Peru and the Democratic Republic of Congo. The price and availability of copper can fluctuate widely because of global demand, social unrest in any of the major producing countries, or changes in trade agreement. Historically, this had lead to dramatic swings in the prices and delivery times of LPT's.

iii) Bushings & Other Accessories

Bushings are a principal accessory of LPT's. Their function is to safely bring the terminals of the windings out through the tank for connection to the terminals of other equipment and the transmission line. Bushings must provide insulation of the winding terminal (lead) through the cover or wall of the electrically grounded tank while preserving the integrity of the tank from dielectric oil leaks.

Bushings are constructed in a number of way, but the condenser designs is most common for high voltages. This design uses a central conductor wrapped with layers of an insulator such as cellulose insulating paper with metallic electrodes called foils placed within. This creates a capacitive effect to reduce the voltage to ground potential at the point where the bushing passes through the tank. The bushing is encases in a housing which has traditionally been made of porcelain and is mounted on the transformer via a flange.

There are many variations of this design. The most common is the use of dielectric oil to impregnate the paper insulation to increase its dielectric strength and cool the conductor. More modern design use resign impregnated paper to avoid the use of oil. Porcelain is slowly being replaced by polymers because of issues with the supply of large, heavy and expensive porcelain housings.

There are a number of global manufacturers of high voltage and high current bushings for LPT's and there is normally not an issue with supply or delivery because despite the long delivery time of very high voltage bushings (16 to 30+ weeks), they are not needed for the manufacture of LPT's until the last phases of testing just prior to shipment. Delivery can become critical if LPT delivery is planned for less than the delivery time of the bushings. Bushing delivery can become critical if they are needed for emergency situations which has lead to major users stocking a number of critical, long lead time bushings for their systems.

Other accessories like on-load tap changers can also have long lead times for specialty models, but this does not normally impede the manufacture of LPT's.

b) **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?**
Using the Defense Production Act Priority Ratings would only apply during major supply disruptions, when global demand is exceptionally high or local supply is not available. There are currently no shortages or other considerations but in cases of emergency could apply to the supply of GOES and copper conductor.

The Defense Production Act Priority Ratings might have a positive influence in obtaining transport equipment like specialty rail cars (Schnabel, super-depressed), large cranes, Goldhofers and dedicated locomotives.

c) **Are there related skilled workforce issues?**
A skilled workforce is critical for the design, manufacture, testing, installation and maintenance of LPT's. The situation described in the IEEE Spectrum in 2000 continues to be accurate. Designing LPT's is a highly specialized branch of power engineering and the number of experienced engineers declined steadily from the 1990's onwards as the result of LPT plant closures coinciding with the onset of deregulation in the electrical industry. The import of LPT's increased as a result of the decline in national manufacturing, decreasing the demand for highly skilled LPT engineers. With new LPT manufacturing capacity being installed, there is a very serious challenge to hire LPT engineers within the country.

The situation for utility power engineers and lineworkers is not dissimilar:

"The electric power industry in the United States is facing a disquieting shortage of trained engineering personnel. For decades, things have gone downhill. The salaries paid to power engineers have been lower than those of virtually all other electrical engineers. Student enrollments have steadily declined. University programs have atrophied. To top things off, as the electric power industry has been radically reorganized in the last 10 years to allow for greater competition, utilities have economized by cutting staff, even as the technical requirements of running their operations have become spectacularly more demanding. While

power engineering has continued to attract engineering school students overseas, where positions in industry enjoy prestige and competitive salaries, the effect has been to aggravate the situation in the United States." **(Badrul H. Chowdhury, IEEE Spectrum October 2000)**

In 2006 the DOE published its report Workforce Trends In The Electric Utility Industry A Report To The United States Congress Pursuant To Section 1101 Of The Energy Policy Act Of 2005 underscoring the situation which has not changed significantly in the last 10 years.

"The electric industry is actively engaged in addressing the lineworker shortage – building awareness of the problem, encouraging training initiatives, and increasing interest in the lineworker profession. However, given the importance of the electricity sector to the economy and security, public-private partnerships may be warranted to promote the energy industry as a viable employment option, to develop strategies for encouraging retirement-eligible workers to remain employed in the industry, and to ensure adequate training and education opportunities to support the reliability and safety of the electricity grid."

7. Manufacturing

a) Is there adequate manufacturing capacity to support a transformer reserve program?

It is unclear if there is sufficient manufacturing capacity in the United States to support a transformer reserve program. This can only be determined once the required quantities and ratings of LPT's for a reserve program have been determined. Technically, there are LPT manufacturing facilities in the United States to produce any required designs, but it is unproven what the total available capacity is. Historically, the majority of LPT's were imported, but with recently added capacity, there may be sufficient capacity.

b) What is the lead time for engineering, manufacture, and delivery of large power transformers?

The lead time for engineering is 1 to 3 months
The lead time for manufacturing is 5 to 16 months (including engineering)
The lead time for delivery is 1 to 3 months depending on size and distance

c) Are there approaches that could help to speed manufacture and delivery of large power transformers?

The production time for an LPT is typically 2 to 4 months based on the complexity of the design. The rest of the 5 to 16 months of total lead time is composed of design time, material acquisition and fabrication backlog. Reducing the total cycle time under normal circumstances is difficult and often requires additional costs to expedite. However, under emergency conditions, significant improvement can be made by:

i) using pre-existing or pre-approved designs

ii) having critical materials on hand or pre-arranged with suppliers for emergency delivery based on the existing designs
iii) having agreements with manufacturers for premium manufacturing slots

Transport time is not easily improved because of the limitations of the existing transport network. Moderate improvements can be made under emergency conditions by utilizing specially contracted ocean vessels or dedicated trains. When available, these options command a large premium to expedite.

8. Transport and Deployment

a) **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?**
Assuming that a portion of the LPT's would also be manufactured overseas, the specialized transport infrastructure necessary to ship LPT's from manufacturing sites to storage locations and from storage to field includes:

i) ocean going vessels with lift capacity for the largest transformers
ii) rail cars such a depressed and super depressed flat cars and Schnabel cars
iii) Goldhofer transporters and other modular trailers to move from rail heads to final storage are if direct rail access is not available
iv) heavy cranes to lift LPT's to and from transport to storage pads

The transport logistics to delivery from storage locations to field sites should be worked out in as part of advanced planning. Such logistics plans would include and pre-clearance from rail authorities, road and bridge permits from authorities, specific site plans for placement with cranes or rigging and installation.

b) **What should be the number and location of transformer storage sites?**
The number and location of transformer storage sites would have to be determined from the optimal solution under the anticipated emergencies (cf. Answer #2).

c) **What are feasible delivery times for LPTs that reside in a reserve to an affected site?**
Assuming that the LPT designs, storage locations are logistics plans are optimized to respond to an emergency, it should be feasible to deliver and install an LPT in less than two weeks and possibly even one.

9. Field Engineering and Installation

a) **Are there adequate domestic engineering and installation resources available throughout the United States to install multiple bulk power transformers simultaneously?**
There appears to be sufficient domestic capacity for engineering and installation resources throughout the United States to install multiple LPT's simultaneously. However, this is based current and normal operating conditions. Reports on

major outages indicate that as little of 10% of personnel and equipment resources could be available under emergency conditions such as major storms, flooding, earthquakes, etc.

b) **What additional resources would be necessary?**
To ensure that critical resources are available even under emergency conditions, it would be recommended that critical resources be made available at the LPT storage facilities. This could include specialty oil processing and vacuum filling equipment, critical spare parts like bushings, and specialty installation and commissioning tools like test equipment. Specialty transport equipment might also be stored at or based out of the storage sites to ensure availability under emergency conditions.

10. Criteria for Deploying Transformers

a) **What criteria should be used for activating and deploying transformers from the reserve?**
Existing spare transformer programs such as STEP operate on the basis of a trigger event (cf. Question #1):

""triggering event," defined as an act of terrorism that destroys or disables one or more substations and results in the declared state of emergency by the President of the United States."

Ownership and funding of the reserve factors into the criteria for activating and deploying transformers from the reserve. Criteria should based on events which could not have been foreseen under the reliability standards set by regulators (FERC, NERC, etc.) or for which the affected owners of the bulk power system could not have been expected to make investments in to account for them or where failure to act immediately would place the bulk power system at serious risk of further degradation due to a sudden or prolonged reduction in resilience. A priority system for allocating resources based on the seriousness of the need and competing requirements during an emergency would have to be developed along the lines of the STEP or NERC programs.

b) **How would deployment be funded?**
Funding of deployment is closely related to the answer from Question #3. Options include the payment of premiums similar to a insurance program for guaranteed deployment or case by case based on actual costs and ROI for the individual transformers deployed or on a standardized fee schedule. Many other schemes could be developed or copied from other industries.

11. Additional Comments

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

a) **Coordination**

An effective National Power Transformer Reserve Program requires significant coordination with all stakeholders, regulators, policy makers and industry participants and not just those directly involved in the bulk power system. This extends to emergency planning organizations whether governmental or not. The list of likely participants to develop, plan and implement an effective program could be extensive and include organizations like NEMA, NOAA, IEEE, NERC, FERC, NARUC, FEMA, DOE, DHS, DOD, DOT, EEI, EPRI plus many others public and private organizations. Coordination and leveraging these resources represents a major challenge.

Of particular concern is the coordination of a reserve program with existing emergency planners at the state or federal level. Each state has developed its own emergency plans for major emergencies and catastrophes. These plans include agreements between states to share or provide support to others during emergencies. The reserve program would logically have to be coordinated with these plans and include the role of individual state PUC's, especially with respect to funding decisions.

Such coordination even extends outside the United States, since the bulk power system includes participants in Canada and Mexico. Historically, participants from Canada and Mexico have provided support during emergencies (e.g. Katrina and Sandy) so coordination at the international level is also recommended.

b) Study, research and data availability

The greatest challenge to respond to this RFI has been the difficulty in obtaining conclusive data on the existing condition of the bulk power system and the risks associated with HILF events or even the reliability of the currently installed base of LPT's.

Outage data as found in the DOE Office of Electricity Delivery & Energy Reliability Electric Disturbance Events (OE-417) reporting and the NERC Transmission Availability Data System (TADS) reporting does not provide sufficient data or detail about outages related to transformer operation and reliability to adequately answer many of the questions posed. It may be that the data does exist, but is not publicly available or not recorded or coded in a useful manner to answer the questions. Data deficiency is addressed highlighted in the NERC AC Substation Equipment Failure Report (ACSETF) December 2014 report.

Some industry data on transformer failure rates and causes is available, but a survey of industry literature indicates that models to predict the failure, time to failure and mode of failure of any particular transformer under normal operating or HILF conditions has not been developed. Such an understanding would be very helpful to understand system reliability and the need for replacement or spare transformers. The development of transformer condition assessment technology needs to be extended to achieve this.