March 27, 2023

Mr. Jeremy Dommu
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Building Technologies Office, EE–5B
1000 Independence Avenue SW
Washington, DC 20585–0121

Re: Energy Conservation Program: Energy Conservation Standards for Distribution Transformers, docket EERE–2019–BT–STD–0018

Submitted electronically to DistributionTransformers2019STD0018@ee.doe.gov

Dear Mr. Dommu,

The National Electrical Manufacturers Association (NEMA) represents nearly 325 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems serving building systems, building infrastructure, lighting systems, industrial products and systems, utility products and systems, transportation systems, and medical imaging. Our combined industries account for 370,000 American jobs in more than 6,100 facilities covering every state. These industries produce $124 billion in shipments and $42 billion in exports of electrical equipment and medical imaging technologies per year.

Members of the NEMA Transformer Products Section share the Department of Energy's (DOE) and the greater efficiency community's interest in reducing distribution transformer losses across the entire U.S. electric grid, as well as within commercial and industrial buildings and other applications. Indeed, NEMA has worked for years developing more efficient, application-specific distribution transformer products to ensure more generation capacity is available to meet demand.

We also support the DOE's commitment to grid modernization, electrification, clean energy development, and a robust U.S. clean energy manufacturing sector.

However, NEMA anticipates that the proposed *Energy Conservation Program: Energy Conservation Standards for Distribution Transformers* Rulemaking (Rule) will, in fact, act as a barrier to these shared priorities. As we explain in detail below, the Rule would contribute to and exacerbate well-known production lead times for distribution transformers, slowing significantly progress toward electrification. It would do nothing to ensure sufficient domestic supply chain inputs for more product efficiency, leaving concerns about U.S. manufacturing capacity unaddressed.

Real questions remain regarding just how energy efficient distribution transformers will become if manufactured to the Rule's new requirements. Particularly, NEMA expresses concerns about these products' implied efficiencies when implemented under actual operating conditions, particularly transformer loading which impacts energy efficiency, as well as other variable changes as the economy continues to electrify.

Furthermore, NEMA is acutely aware of the Administration's concern regarding the need to increase domestic distribution transformer production as evidenced by the inclusion of transformers in President Biden's June 6, 2022 invocation of the Defense Production Act (DPA) for clean energy technologies.

Specifically, the DPA order authorized "*the Department of Energy to use the DPA to rapidly expand American manufacturing of five critical clean energy technologies.*" including "*critical power grid infrastructure like transformers.*" Not only is NEMA unaware of actions taken by DOE to achieve this DPA objective, but, as demonstrated in our comments below, the Rule will in fact be counterproductive to that goal, further constrain and hinder the domestic production of distribution transformers, and increase reliability, security, and resiliency risks to the U.S. electrical grid.

While our comments below highlight the many serious problems with the proposed rule, NEMA stands ready to work with DOE, other Departments, and Agencies to create the conditions in which energy conservation standards for distribution transformers can be achieved in ways that increase domestic manufacturing capacity, save energy, enhance grid reliability, boost electrification, and foster clean energy.

Supply Chain Problems Associated with the Proposed Rule

As proposed, the Rule seeks to achieve greater levels of energy efficiency in distribution transformers by requiring that its core components be manufactured using amorphous steel. On paper, this proposal can be achieved under controlled and assumed situations; however, in practice this proposal is resoundingly unachievable mainly due to the absence of an existing supply chain needed to meet the Rule's expectations at scale and assumptions about the energy efficiency performance of amorphous steel cores that are likely unachievable in application. The proposal completely underestimates or simply ignores the market, political, and regulatory variables necessary to stand up a secure and resilient domestic supply chain for critical infrastructure materials and components.

The Administration is acutely aware of the fragility of existing supply chains across all economic sectors. In his February 24, 2021 Executive Order, President Biden stated that the United States needs "*resilient, diverse, and secure supply chains to ensure our economic prosperity and national security.*"[1]

Further, he noted that "*more resilient supply chains are secure and diverse—facilitating greater domestic production, a range of supply, built-in redundancies*". As proposed, the Rule focuses solely on a single element of this list of necessities – domestic production – while downplaying or disregarding others. NEMA members acknowledge and support the need to increase domestic production and manufacturing of goods, and government plays an important role in incentivizing this type of investment. However, mandating through regulation a single variable at the expense of others among a supply chain creates a dangerous imbalance.

Moreover, the Administration further acknowledged the seriousness of distribution transformer supply chain complexities when President Biden, on June 6, 2022, took executive action by invoking the Defense Production Act (DPA) to accelerate domestic production of clean energy technologies, including "*critical power grid infrastructure like transformers.*"[2] It is incongruent and counterproductive for the Administration to declare in one breath that distribution transformers are in such short supply that government must turn to the DPA to increase output, while in the next breath propose regulatory action which would dramatically complicate and confuse the supply chain, lengthen production lead times, and put the grid at greater risk.

Distribution transformer production relies on a diverse supply chain to source parts and components to meet the American market demand for such products. Transformer cores made from grain-oriented electrical steel (GOES) are both manufactured in-house by NEMA members and purchased from third party sources. However, domestic transformer electromanufacturers do not currently have the ability to

[1] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/

[2] https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/06/fact-sheet-president-biden-takes-bold-executive-action-to-spur-domestic-clean-energy-manufacturing/

produce amorphous steel cores internally, requiring them to be purchased exclusively from third parties. Through its proposed Rule, the Department would require every manufacturer to shift their diverse and reliable supply chain and internal capabilities and rely on external vendors to supply this critical component unless significant capital expenditures were implemented. Mandating single-sourcing of materials not only creates severe risks and uncertainties in a product's order cycle – which in turn imposes higher costs on electric utilities, homebuilders, and customers – it goes against the Administration's own policy goal of supply chain diversification and built-in redundancy.

In the case of amorphous steel cores, we know of just a single domestic manufacturer currently offering these components. To our knowledge, this manufacturer is the only company which has made the investment necessary to bring such a product to market, on any scale. Furthermore, this one company does not appear to have any market competition. Due in part to capital intensive start-up costs and lengthy permitting processes associated with the domestic manufacturing of amorphous steel cores, new capacity to increase production quickly to meet current demand, let alone increased future demand, is unlikely in the foreseeable future. There are no companies standing up new amorphous steel production lines, nor are there any federal funding initiatives aimed at expanding domestically amorphous steel manufacturing.

The proposed Rule has the potential to accentuate an already monopolistic situation in the distribution transformer market. An unchecked, federally endorsed monopoly on critical manufacturing material will also work against the Administration's grid modernization and electrification goals by dramatically increasing costs and lead times. Further, we believe the Rule may run afoul of anti-trust statutes.

In addition to how the Rule would severely impact the production of distribution transformers, the requirement of amorphous steel cores also creates downstream logistical issues, which in turn enhance risks to grid resiliency and reliability. First, the physical properties of transformers which utilize amorphous core are often considerably larger in size and much heavier relative to a competing non-amorphous core. This will require manufacturers to reconfigure their assembly processes, including time to retrain electricians to match transformer coils to calibrate with the properties of the new steel. The hand-made coils will require considerably more steel, adding weight to enable the performance required by the proposed Rule. Further, the steel tanks which house both the coil and cores will need to be reconfigured to match these new dimensions.

Second, the transportation, delivery, and implementation of these new products will also be impacted. The increased size means fewer units per truck, thus larger and heavier equipment will require more trucks to move such equipment to their installation locations. Larger and heavier means that for pole-mounted transformers, new poles to support the weight will have to be sourced; for pad-mounted transformers, thicker and larger concrete pads will have to be poured. Larger and heavier also means bigger boom cranes necessary to lift such equipment will need to be procured. When taken together, the affiliated emissions that will come from amorphous core transformers – including from excess tailpipe emissions due to increased trucking to industrial carbon from greater concrete usage – could, ironically, counter many of the efficiency gains the Rule is attempting to achieve.

NEMA has been a long-time advocate for product efficiency; however, the timing and intent of the proposed Rule would severely undermine many of the long-term clean energy policy goals of the Department, Congress, and the Administration. By requiring manufacturers who are already under immense pressure to reduce lead times for distribution transformers – currently 16-plus months – to shift their steel supply to an untested, less flexible, and more expensive source is perilous to our national security, grid resiliency and infrastructure buildout.

DOE Scaling Factors

NEMA members have a number of concerns about the manner in which DOE has applied scaling factors in the development of this proposed Rule.

DOE made use of the ¾ kVA function to estimate weights, costs, and losses in going from one kVA size to a second one to simplify the engineering analysis. This estimating method is considered generally accurate when considered within a narrow band of power ratings and only when general construction, voltage classes and winding conductor remain the same. This formula is described in detail as to its application in Section 5.2.2 of the TSD from DOE.

The scaling factor (or scaling exponent) has traditionally been assigned a value of 0.75. However, DOE assigned slightly different values to the scaling exponent which are defined in Table 5.2.4 in the TSD (shown below) based on data received in 2013.

Table 5.2.4 Scaling Exponents by Equipment Class

Distribution Transformer Equipment Class	Scaling Exponent
1. Liquid-immersed, medium-voltage, 1-phase	.76
2. Liquid-immersed, medium-voltage, 3-phase	.79
3. Dry-type, low-voltage, 1-phase	.75
4. Dry-type, low-voltage, 3-phase	.74
5. Dry-type, medium-voltage, 1-phase, 20-45 kV BIL	.67
6. Dry-type, medium-voltage, 3-phase, 20-45 kV BIL	.67
7. Dry-type, medium-voltage, 1-phase, 46-95 kV BIL	.67
8. Dry-type, medium-voltage, 3-phase, 46-95 kV BIL	.67
9. Dry-type, medium-voltage, 1-phase, ≥ 96 kV BIL	.68
10. Dry-type, medium-voltage, 3-phase, ≥ 96 kV BIL	.68

DOE applied this formula to designs created by The Transformer Design Program (TRANS) published by the Optimized Program Service, LLC of Strongsville, OH, commonly referred to by transformer engineers as “OPS”, thereby creating a massive database of cost, design, and loss information for all different kVA’s within their respective equipment classes. It is this data the DOE used for its analysis.

However, as mentioned above, this method is not appropriate for estimating when considering large ranges of transformer kVA ratings.

A NEMA member provided the below analysis of the scaling exponent specifically related to medium voltage dry-type transformers showing wide swings in actual scaling factors computed from real designs. The analysis also demonstrates that only narrow bands of kVA sizes close to the sizes of the representative design units managed to fall within 5% of the results computed by the DOE using their scaling factor. The results of this analysis are summarized below.

Analysis Assumptions

- All designs are round coils
- All designs based on DOE 2016 efficiencies
- Smaller kVA sizes constrained by realistic wire sizes and UL required construction
- All designs are typical close coupled unit-substations
- Designs are driven off lowest cost outcome
- Equipment Class 6 are barrel wound
- Equipment Class 8 are continuous disk wound HV
- Designs constrained to industry accepted impedances of 5.00% to 5.75%

					MATERIAL COST		Actual Value Within 5% of DOE Calculation	
Voltage (kV)	BIL (kV)	Equipment Class	Conductor	SF Used by DOE	Actual Min (SF)	Actual Max (SF)	Scaled from 300 kVA	Scaled from 1500 kVA
5	30	6	AL	0.67	0.33	1.11	None	750, 1000
15	95	8	AL	0.67	0.14	0.98	None	1000
5	30	6	CU	0.67	0.34	1.13	150, 225, 500	None
15	95	8	CU	0.67	0.32	0.86	None	500, 750, 1000

					NO LOAD WATTS		Actual Value Within 5% of DOE Calculation	
Voltage (kV)	BIL (kV)	Equipment Class	Conductor	SF Used by DOE	Actual Min (SF)	Actual Max (SF)	Scaled from 300 kVA	Scaled from 1500 kVA
5	30	6	AL	0.67	0.33	0.88	225, 500	750, 1000, 2000, 2500
15	95	8	AL	0.67	0.37	0.86	150, 225	1000, 2000, 2500

					FULL LOAD WATTS		Actual Value Within 5% of DOE Calculation	
Voltage (kV)	BIL (kV)	Equipment Class	Conductor	SF Used by DOE	Actual Min (SF)	Actual Max (SF)	Scaled from 300 kVA	Scaled from 1500 kVA
5	30	6	AL	0.67	0.51	0.88	500	750, 1000, 2000, 2500
15	95	8	AL	0.67	0.54	1.02	150, 225, 500	750, 1000, 2000, 2500

Table 1: Scaling factor analysis based on current 2016 efficiency requirements for medium-voltage distribution transformers.

Note: Scaling factors / exponents were computed based on actual cost and loss information for each kVA size relative to the 300 kVA for the 15 to 500 kVA range and relative to the 1500 kVA in the 750 to 2500 kVA range.

Actual scaling factors can be seen to be relatively accurate when considering kVA sizes relatively close to the representative designs of 300 and 1500 kVA in Equipment classes 6 and 8. Scaling factors are seen to increase with kVA from as low as 0.14 to as high as 1.02. The reasons for this are primarily design constraints on available wire sizes, maintaining impedances in the 5.00% to 5.75% range and specific construction requirements for Underwriter Laboratory requirements. Also, note in the smaller kVA sizes, small wires become very expensive and difficult to use and greatly inflate the prices relative to the kVA size causing a skew in the cost curve. DOE recognized this in the 2013 rulemaking and skewed the efficiency increases to be smaller or zero for the lower kVA's. The 2022 NOPR makes no similar adjustments. The DOE has used OPS software over multiple voltage classes and efficiencies and the scaling factor methodology was used to derive data for the other kVA sizes.

Another limitation to using the scaling factor is the effect of stray and eddy losses on efficiency performance:

- Higher voltage classes have much lower space factor of conductors in the core window because of the need for thicker insulations.
- Eddy current losses within a winding vary as the 4th power of conductor thicknesses and need to be included in scaling but have not been.
- Higher efficiencies require much lower current densities that result in thicker conductors and result in much higher eddy losses.
- Higher currents also result in higher stray losses associated with induced losses from current flowing in leads and buses in the core clamps and tanks. The DOE scaling has ignored this.

Another concern is kVA sizes greater than 2000 kVA with low output voltages call for efficiencies that in some cases cannot be reached with GOES and require the use of copper to lower conductor losses to meet the higher efficiency levels. Designs using GOES to meet the proposed NOPR efficiencies have been shown to force flux densities down to 10 kG or below to lower core losses enough to meet the required efficiency levels. Practical and more realistic flux densities are typically in the 14 to 15 kG range. Flux density levels being forced into the 10 kG range are a clear indication that the design limits for using GOES are at or beyond their technical and economic feasibility. As transformer kVA's increase, lower secondary voltages cause significant increases in buss and lead losses particularly for transformers having 208Y/120 secondary connections. These higher losses in turn constrain no-load (core) losses to be even lower which is why the induction levels are so low to make the designs work. Medium voltage liquid and dry type unit weight increases of 50% generally result in 15% taller, wider, and deeper units compared to those designed to meet the 2016 DOE rule. Sensitive installation locations are an issue. Tank diameters and/or tank heights increases of 15% or more will create new logistical challenges.

Low voltage dry type transformer weights, when constructed with GOES, increase up to 250%, as does cost when designs were possible. However, proposed efficiencies in the NOPR are either impossible or impractical using GOES for many designs, especially in the higher kVA ranges as is evidenced by the DOE's own scatter plots for RU6, RU7 and RU8.

Indoor power modules (lineups) with efficiency levels optimized at 35% load result in larger footprint designs which will complicate these installations where space is at a premium. Furthermore, transformers may even operate less efficiently where average loads are well above the 35% levels.

Significantly higher efficiency levels drive impedance levels lower especially when using GOES steel. Maintaining impedance levels above 4.00% and preferably above 5.00% to prevent excessive fault currents becomes very difficult to maintain. This is a problem when it comes to designing a power system and choosing circuit breakers or fuses which are capable of handling the higher fault currents due to lower transformer impedances in low voltage distribution branch circuits.

Section VII. E. *Issues on Which DOE Seeks Comment*

In Appendix A, NEMA Transformer Products Section member companies offer responses to the specific questions posed by the Department in the NOPR.

It is with a considerable sense of frustration that we submit these comments as they would be more detailed and better reflect our full collective view had industry been afforded more time to develop them. While the two additional weeks added to the comment period were somewhat helpful, they were insufficient and offered before NEMA could add its voice to the chorus of organizations requesting more time. Given the depth of information sought by the Department and the technical complexities of the subject matter, NEMA members needed a minimum of 180 days to fully address the Department's questions and data requests. Nevertheless, we appreciate the opportunity, albeit limited, and remain available to answer additional questions.

For all the reasons we present here, we request that the Department issue a Notice of Proposed Determination indicating that energy conservation standards for distribution transformers do not need to be amended because more stringent standards are not economically justified nor in the national interest at this time.

Sincerely,

Alex Baker
Director, Regulatory Affairs
National Electrical Manufacturers Association

Appendix A

Section VII. E. ***Issues on Which DOE Seeks Comment***

1) DOE requests comment on the proposed amendment to the definition of drive (isolation) transformer. DOE requests comment on its tentative determination that voltage ratings of 208Y/120 and 480Y/277 indicate a design for use in general purpose applications. DOE also requests comment on other voltage ratings or other characteristics that would indicate a design for use in general purpose applications.

NEMA members agree that voltage ratings are a poor measure to capture these distinctions.

2) DOE requests comment on its proposed amendment to the definition of "special-impedance transformer" and whether it provides sufficient clarity as to how to treat the normal impedance ranges for non-standard kVA distribution transformers.

NEMA members recommend that kVA be specified in ranges. The normal impedance range for each kVA rating for liquid-immersed and dry-type transformers is show below in Tables 1 and 2, respectively. We offer these tables as recommended replacements for the Tables 1 and 2 proposed in the NOPR definition of *special-impedance transformer*. Addressing kVA ratings not appearing in the table, the new tables recommended below supply the normal ranges for IZ for all units within scope.

Single-Phase		Three-Phase	
kVA	**Impedance (%)**	**kVA**	**Impedance (%)**
10.0 – 49.9	1.0 – 4.5	15.0 – 74.9	1.0 – 4.5
50.0 – 249.9	1.5 – 4.5	75.0 – 112.4	1.0 – 5.0
250.0 – 499.9	1.5 – 6.0	112.5 – 499.9	1.2 – 6.0
500.0 – 666.9	1.5 – 7.0	500.0 – 749.9	1.5 – 7.0
667.0 – 833.0	5.0 – 7.5	750.0 – 5000.0	5.0 – 7.5

Table 1: For liquid-immersed distribution transformers

Single-Phase		Three-Phase	
kVA	**Impedance (%)**	**kVA**	**Impedance (%)**
15.0 – 74.9	1.5 – 6.0	15.0 – 224.9	1.0 – 4.5
75.0 – 166.9	2.0 – 7.0	225.0 – 499.9	3.0 – 7.0
167.0 – 249.9	2.5 – 8.0	500.0 – 749.9	4.5 – 8.0
250.0 – 666.9	3.5 – 8.0	750.0 – 5000.0	5.0 – 8.0
667.0 – 833.0	5.0 – 8.0		

Table 2: For dry-type distribution transformers

3) DOE requests comment on its proposed definition for transformers with a tap range of 20 percent or more.

The proposed definition is clear.

4) DOE requests comment on its proposed amendments to the definitions of sealed and nonventilated transformers.

We agree with the proposed amendments.

5) DOE requests comment on its proposed amendment to the definition of uninterruptable power supply transformers.

UPS-specific transformers must meet design criteria that prevent them from complying with DOE's proposed efficiency requirements, and their market volume is extremely small compared to the distribution transformer market. NEMA members recommend that the definition be modified to include the attributes that prevent UPS transformers from meeting the proposed efficiency requirements. Transformers that do not include at least one of these attributes, will not meet the definition of a UPS transformer and would therefore have to meet the proposed distribution transformer efficiency requirements. We recommended the underlined addition to the definition, as follows:

> "*Uninterruptible power supply transformer* means a transformer that is used within an uninterruptible power system, which in turn supplies power to loads that are sensitive to power failure, power sags, over voltage, switching transients, line noise, and other power quality factors. <u>These transformers must include a core with an air gap and/or a shunt core."</u>

6) DOE requests comment as to whether its proposed definition better aligns with industries [sic] understanding on input and output voltages.

The addition of line voltage to the definition removes ambiguity and clearly defines products that need to be in compliance. However, the definition for low-voltage dry-type transformer needs to be updated with the main definition.

Related, there is remaining confusion regarding the applicability of this regulation to LVDT step-up designs. Since 600 volts is the value for both input and output on LVDT units, both step up and step down appear to be within the current scope. Products that would benefit from this clarification include 208 to 480Y/277; 240 to 480Y/277; 480 to 600Y/347; and 208 to 240, to name a few.

We note that step-up is not mentioned in the main definition but is included in the LVDT sub-definition. This should be corrected. We recommend the additions underlined below.

> *"The term 'low-voltage dry-type distribution transformer'* means a distribution transformer that—
>
> (A) has an input <u>line</u> voltage of 600 volts or less
> …
> <u>(D) since both input and output are 600 volts or less – all step up and step down products are included in scope</u>*"*

7) Further, DOE requests comment and data on whether the proposed amendment would impact products that are serving distribution applications, and if so, the number of distribution transformers impacted by the proposed amendment.

Yes, the proposed amendment would impact all medium voltage distribution transformers. NEMA members support the proposed clarifications.

8) DOE requests comment and data as to whether 5,000 kVA represents the upper end of what is considered distribution transformers or if another value should be used.

NEMA members request clarification on DOE's intent. We have observed that customers will sometimes place orders for equipment with specifications just beyond the scope of regulations, e.g., 2501 kVA, or 5001 kVA.

11) DOE requests comment on its understanding and proposed definition of "submersible" distribution transformer. Specifically, DOE requests information on specific design characteristics of distribution transformers that allow them to operate while submerged in water, as well as data on the impact to efficiency resulting from such characteristics.

It is our understanding that a submersible distribution transformer as per IEEE C57.12.24-2016 and IEEE C57.12.40-2017 are already quite clearly defined and extremely difficult to deviate from. The special installation characteristics of such transformers result in these units having a very special design, with characteristics rarely comparable with other types of distribution transformers installed above ground. Additionally, IEEE C57.12.80-2010 defines as a common point the vault installation to several submersible applications (i.e., submersible transformer, subway transformer, network transformer), which is also very important for this definition.

Regarding DOE's proposed definition, we believe it is unnecessary to set proposed features (1) and (2) as a rule for the definition, since some utilities have been using 65 °C as temperature rise rating. Additionally, on proposed feature (4) we would also recommend adding that the unit can also have surface treatment for corrosion resistance capabilities. With the above comments, we would amend and recommend the following changes to the definition, with deletions in strikeout and additions underlined:

> "*Submersible Distribution Transformer* means a liquid-immersed distribution transformer, so constructed as to be successfully operable when fully submerged in water including the following features: (1) ~~is rated for a temperature rise of 55°C~~ has sealed tank construction; (2) ~~has insulation rated for a temperature rise of 65°C; (3) has sealed-tank construction; and (4)~~ has the tank, cover, and all external appurtenances made of corrosion-resistant material or with appropriate corrosion resistance surface treatment to induce the components surface to be corrosion resistant; and (3) is designed for installation in an underground vault."

The following points affect the design and limit typical solutions to increasing efficiency:

Submersible transformers are usually installed in vaults, with very strict dimensional requirements, limiting the options to increase the design efficiency.

While operating submerged, the thermal efficiency of submersible transformers drops. Dirty water and debris can negatively impact the effective heat transfer to external surfaces, limiting options to further increase efficiency of such units.

Corrosion resistance usually denotes that this type of transformer features more robust construction regarding tank wall thickness, radiator thickness and surface treatments. All of these decrease the thermal efficiency of such units and affect their capability to regulate transformer operating temperatures and reduce associated losses. While increasing the efficiency would reduce losses and thermal requirements, usually the dimensional limits of existing vaults serve as the primary the limiting factor.

12) DOE requests comment and data as to the impact that submersible characteristics have on distribution transformer efficiency.

Given the project-specific impacts of distribution transformer submersion, it is not possible for manufacturers to provide such data. We recommend the Department consult electric utilities for such data.

13) DOE requests data on the difference in load loss by kVA for distribution transformers with multiple-voltage ratings and a voltage ratio other than 2:1.

Due to the myriad ways distribution transformers can be constructed, and that different voltage ratios would necessarily lead to different design philosophies, such data would be exceedingly laborious for industry to develop. NEMA members request clarification on what question(s) the Department seeks to answer.

14) DOE request data on the number of shipments for each equipment class of distribution transformers with multi-voltage ratios other than 2:1.

NEMA members lack data to provide to the Department, however we believe the equipment in question represents less than 2% of the overall distribution transformer market.

15) DOE requests data on the difference in load loss by kVA for distribution transformers with higher currents and at what current it becomes more difficult to meet energy conservation standards.

For liquid-filled medium voltage distribution transformers, it is difficult to meet energy conservation standards above roughly 4000 amperes with today's minimum efficiency requirements.

For dry-type medium voltage distribution transformers, the answer is less clear. The number of variables involved in designing transformers to meet the unique needs of each application make it difficult to calculate on answer.

For liquid-filled or dry type, NEMA members recommend the Department avoid increasing efficiency requirements for distribution transformers with a low voltage line current rating of more than 3000 amperes.

16) DOE requests data as to the number of shipments of distribution transformers with the higher currents that would have a more difficult time meeting energy conservation standards.

Further information would be required to answer this question, for instance, at which current values the data are sought.

19) DOE requests comment regarding any challenges that would exist if designing a distribution transformer which uses amorphous electrical steel in its core for data center applications and whether data center transformers have been built which use amorphous electrical steel in their cores.

Low voltage dry-type (LVDT) products have not employed amorphous cores in the United States market for any known applications including data centers. For data center projects, the use of amorphous cores will not maximize the energy savings benefits for the application since the units are typically loaded between 65 to 80%, making coil loss more important than the core loss portion and limiting the overall benefit of amorphous cores. Another concern is the need for transformers to be energized multiple times via transferring power from one source to another. During the transferring of power, coordination between the transformer maximum inrush and over current protective device must prevent nuisance tripping of the system. The use of GOES via stacked cores, instead of wound core required for amorphous construction, reduces inrush values via inherent air gaps. Via the design process for limiting inrush, the designer looks for high saturation flux density; amorphous cores tend to have levels 80 to 85% of GOES material. The last area where amorphous would negatively impact the inrush currents is the remanent flux density (flux density retained by the core); amorphous cores hold approximately 90% where GOES material holds around 80%.

20) DOE requests comment on the interaction of inrush current and data center distribution transformer design. Specifically, DOE seeks information regarding: (1) the range of inrush current limit values in use in data center distribution transformers; (2) any challenges in meeting such inrush current limit values when using amorphous electrical steel in the core; (3) whether using amorphous electrical steel inherently increases inrush current, and why; (4) how the (magnetic) remanence of grain- oriented electrical steel compares to that of amorphous steel; and (5) other strategies or technologies than distribution transformer design which could be used to limit inrush current and the respective costs of those measures.

These questions need to be addressed across all applications for LVDT products, not only data centers. Manufacturers of data center design transformers have these concerns due to challenges faced meeting current regulations, however these challenges will now be faced potentially in all applications that install LVDT units. Some applications will only see the issue during installation and power loss, but as alternate power systems increase in the market more LVDT units will have power transferred from one source to another. NEMA members are entering these comments with respect to all LVDT applications, inclusive of data center applications.

(1) Regarding the range of inrush current:

The maximum inrush must be designed to be on the left of the over current trip curve, allowing the device to continue to function even when seeing maximum inrush from the transformers.

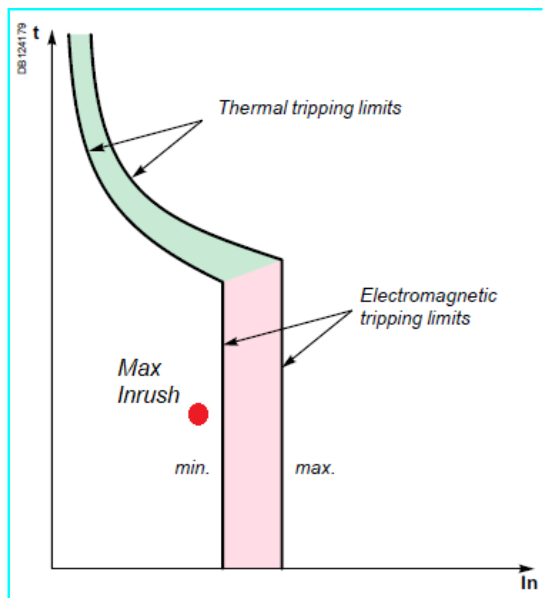

Figure 1: Trip curves with low-voltage distribution transformer inrush, Schneider Electric.

(2); (3); and (4): please see reply in question 19.

(5) Regarding the design of not only the transformer but the full distribution system, the following must be taken into account during the design: the higher the steel quality, the higher:

- the potential inrush
- the coil-winding geometry, i.e., length and diameter of coils
- the core configuration
- number of turns in the energized winding

Addressing inrush current that may cause nuisance tripping may be accomplished via other components:

- Inserting resistance during energization of a transformer, also known as soft start, needs to be incorporated in the static transfer switch (STS) system for data center applications but would need to be added into the breaker or fusible safety switch on other applications.

- Coordinating the primary overcurrent protection trip curves to align with the maximum inrush current from the transformer by:
    - Employing electronic breakers with adjustable trip settings, increasing the costs for these transformers by obtain the highest price point device for protection; or,
    - Designing the electrical system with the maximum allowed primary overcurrent protective device permitted by NFPA 70, National Electrical Code. This method will also require transformer secondary overcurrent protection into the system design on LVDT units to properly protect the entire system, adding cost by adding components to the system not required today.

22) DOE requests comments and data on any other types of equipment that may have a harder time meeting energy conservation standards. Specifically, DOE requests comments as to how these other equipment are identified based on physical features from general purpose distribution transformers, the number of shipments of each unit, and the possibility of these equipment being used in place of generally purpose distribution transformers.

Distribution transformers presenting the greatest difficulty meeting energy conservation standards are those intended to fit into existing pre-defined spaces that are incapable of accepting larger equipment.

For liquid-filled medium voltage distribution transformers, overall physical dimensions expand as efficiency requirements increase. Building transformer vault spaces, however, are fixed during original construction and typically cannot be expanded. Outdoors, pad sizes are particularly constrained in urban locations, limiting distribution transformer overall dimensions.

NEMA members ask the Department to consider not including shovel transformers, above ground mining transformers, crane duty transformers, and marine application transformers.

26) DOE requests data as to how stray and eddy losses at rated PUL vary with kVA and rated voltages.

Stray loss for 3-phase liquid-filled designs and dry types, associated with bus bars passing clamps and enclosures, wherein LV denotes low voltage, and dc denotes direct current:

Stray Loss = LV Volts* Amps^2/923000

LV eddy loss varies as a percent of the dc winding loss:

Eddy percent of dc I^2*R for copper foil = 0.041*(f^2)*(t^4)*4*(Layers^2)-1)

Eddy percent of dc I^2*R for aluminum foil = 61.5% of the copper percent

An example:

> Suppose we have a 3750 kVA rating with LV 480 Y/277 volts and current of 4512 amps with aluminum strip LV at 0.157” thick with 8 LV turns and a dc loss of 9462 watts
>
> Stray loss = 277 volts*(4512 amp)^2/923000= 6109 watt

Eddy loss % = 0.615*0.041*(60^2)*(0.157^4)*(4*(8^2)-1)= 14.1%

Eddy loss watts =0.141*9462 = 1334 watts.

The combined stray and eddy loss = 7443 watts

This combination of stray and eddy = 7443/9452 or 79% of the dc loss

This set of relationships say that as the LV current rises that stray and eddy rise as the current squared and that total loss in watts no longer vary as the kVA to the ¾ power. Power ratings above 2500 kVA could not meet the proposed NOPR without extreme measures. It is doubtful that the designs from OPS software recognize these relationships, especially above 2500 kVA.

29) DOE requests comment regarding the barriers to converting current M3 or 23hib90 electrical steel production to lower-loss GOES core steels.

Low loss steels would need to be operated at low flux densities where their loss characteristics are similar to M3. Steels with better characteristics than M3 are not normally available from domestic suppliers.

31) DOE requests comment on how a potentially limited supply of transformer core steel, both of amorphous and GOES, may affect core steel price and availability. DOE seeks comment on any factors which uniquely affect specific steel grades (e.g., amorphous, M-grades, hib, dr, pdr). Additionally, DOE seeks comment on how it should model a potentially concentrated domestic steel market in its analysis, resulting from a limited number of suppliers for the amorphous market or from competition with NOES for the GOES market, including any use of game theoretic modeling as appropriate.

Distribution transformer manufacturing relies on two primary supply chains: core manufacturing and rolled steel manufacturing.

NEMA Transformer Products Section members know of only one domestic manufacturer of amorphous cores. Consequently, core manufacturing is anticipated to be the likely bottleneck in the distribution transformer market should the Department's Rule be finalized and enforced as proposed. For economic modeling purposes, we trust that the Department of Energy well understands the anticipated economic impacts that would result from an entire industry's reliance on one single company for critical manufacturing materials.

Current DOE regulations for distribution transformers allow steel mills to sell multiple grades of steel to support distribution transformer manufacturing. While not publicly recognized by suppliers, pricing of rolled steel products used by distribution transformer manufacturers is affected by global demand. Some grain-oriented electrical steel (GOES) manufacturers outside of the U.S. have publicly stated that they have committed part of their production capacity to their domestic markets, thus making such supply unavailable to support changes in the U.S. transformer market.

Should DOE move forward with the proposed Rule, the higher performance requirements combined with these market realities can only result in predictable, dramatic cost increases across the distribution transformer market.

35) DOE requests comment on its assumed TOC adoption rate of 10 percent. Specifically, DOE requests comment on the TOC rate suggested by NEMA, that between 15 and 20 percent of 3-phase liquid-immersed distribution transformers are purchased using TOC, and that 40 percent of 1-phase liquid-immersed distribution transformers are purchased using TOC. DOE notes, that it is seeking data related to concluded sales based on lowest TOC in the strictest sense, excluding those transformers sold using band of equivalents (see the section on band of equivalents, above)

The percentage of transformers currently being purchased using TOC is estimated to be lower than 10% for both single-phase and three-phase transformers. This is the result of implementation of DOE's current minimum efficiency levels (April 2013 regulation) as the TOC formula became less relevant when defining the most cost competitive transformer design option. Most customers are purchasing transformers based on lowest first cost that meet the current DOE-mandated efficiency levels.

36) DOE requests comment on the fraction of distribution transformers purchased by customers using the BOE methodology. DOE notes, that it is seeking data related to concluded sales based on lowest BOE in the strictest sense, excluding those transformers sold using total owning costs.

Band of equivalence (BOE) is generally not used for low- or medium-voltage dry-type transformer purchases.

37) DOE request comment if the rates of TOC or BOE vary by transformer capacity or number of phases. Further, DOE seeks the fraction of distribution transformer sales using either method into the different regions in order to capture the believed relationship between higher electricity costs and purchase evaluation behavior.

TOC A/B factor values do not vary by transformer capacity or number of phases. Most utilities who use TOC methods also apply a band of equivalency, ranging from 3-10% of the TOC, where the lowest first cost transformer in the band is purchased.

40) DOE request the average extension of distribution transformer service life that can be achieved through rebuilding. Additionally, DOE requests comment on the fraction of transformer that are repaired by their original purchasing entity and returned to service, thereby extending the transformer's service lifetime beyond the estimated lifetimes of 32 years with a maximum of 60 years.

To more fully answer this question NEMA members request the Department's definition of 'rebuilding'. Rebuilding, as we understand it, does not typically occur with liquid-filled distribution transformers. When rebuilding is undertaken, it is typically a consequence of equipment failure unrelated to end-of-life. To our knowledge, no one is rebuilding low-voltage distribution transformers. So-called rewind shops are wholly separate entities from distribution transformer manufacturers.

41) DOE requests comment on which liquid-immersed distribution transformers capacities are typically replaced with MVDT. DOE further requests data that would indicate a trend in these substitutions. DOE further requests data that would help it determine which types of customers are <u>pre</u>forming these substitutions, e.g., industrial customers, invertor [sic] owned utilities, MUNIs, etc.

This is not a typical replacement. These two types of distribution transformers coexist in the market.

42) In response to NEMA's comment DOE requests data to inform a shift in the capacity distribution to larger capacity distribution transformers. Additionally, DOE requests information on the extent that this increasing trend in capacity would affect all types of distribution transformers, or only medium-voltage distribution transformers.

Roughly 15% of the low voltage commercial market is increasing their distribution capacity sizes, going from 500 kVA to 1000 or 1500 kVA.

43) DOE projected the energy savings, operating cost savings, product costs, and NPV of consumer benefits over the lifetime of distribution transformers sold from 2027 through 2056. Given the extremely durable nature of distribution transformers, this creates an analytical timeframe from 2027 through 2115. DOE seeks comment on the current analytical timeline, and potential alternative analytical timeframes.

NEMA considers that the current estimation of transformer lifetime of 32 years is adequate. Although it is recognized that distribution transformers have an extremely durable nature, other factors that might affect the lifetime should be considered, such as transformer replacements due to potentially higher rates of load growth due to increased electrification initiatives.

44) DOE requests comment on its assumption that including a rebound effect is inappropriate for distribution transformers.

We understand that the Department defines the rebound effect as "*an increase in utilization of the equipment due to the increase in efficiency and its lower operating cost*" (NOPR section IV.H.2). NEMA members agree with the Department's conclusion that such an effect need not be incorporated into its analyses.

45) DOE requests comment on the mean PUL applied to distribution transformers owned and operated by utilities serving low customer populations.

For liquid-filled transformers, in these instances NEMA members estimate PUL would typically be 10% of RMS-equivalent nameplate rating.

48) DOE requests comment on the estimated potential domestic employment impacts on distribution transformer manufacturers presented in this NOPR.

The Rule as drafted would require intensive capital expenditures by any company wishing to remain viable in the distribution transformer market in the United States. Such expenditures would most likely come with negative impacts on employment. With the Rule in force, core manufacturing is likely to shift from in-house to outsourcing, which could shift those jobs overseas. While roughly 80% of low voltage dry-type are already manufactured in Mexico or India, medium voltage dry-type products, including their cores, are still predominantly produce domestically. The Department has the opportunity to preserve this domestic manufacturing base. Should the Department elect to set performance requirements effectively mandating amorphous steel cores, small domestic manufacturers of distribution transformers would likely cease operations as they would have no choice but to outsource cores from a single domestic amorphous core manufacturer enjoying a monopolistic hold on the market.

49) DOE requests comment on the potential availability of either amorphous steel, grain- oriented electrical steel, or any other materials that may be needed to meet any of the analyzed energy conservation standards in this rulemaking. More specifically, DOE requests comment on steel manufacturers' ability to increase supply of amorphous steel in reaction to increased demand for amorphous steel as a result of increased energy conservation standards for distribution transformers.

NEMA members note that the scale-up of amorphous steel production to provide an additional 70,000 metric tons annually (verbally stated by a Metglas, Inc. representative on the Department's 16 February 2023 webinar) would be insufficient to support the new distribution transformer market that would be created by the proposed Rule.

It is imprudent for the Department of Energy to impose a new energy conservation standard requiring market capacity that does not yet exist, indeed, to impose requirements that rely on an entirely speculative supply of amorphous steel that does not exist. Instead, NEMA members encourage the Department to consider implementing another rulemaking after the proposed scaling up has occurred.