Distribution Transformer Working Group: Guide to understanding and using the enclosed information.

The focus of this effort was to support the following short-term goals in addition to providing information for longer term strategies with input from a selection of Utilities and Transformer manufacturers. Each goal is discussed with some background on why this effort was investigated and some insight on how to interpret the information provided.

GOAL #1: Distribution Transformer Taxonomy Table

In the initial discussions, it was clear that there was need to ensure that everyone in the group was using the same terminology and understanding for different critical components and operations within this space. A general taxonomy table was derived from IEEE standards, RUS documents, and design specifications to align the baseline terminology and impact to ratings, design, and manufacturing. This table is considered a reference for the transformer attributes to be considered for the remainder of the discussions and provide a clear communication among varying levels of technical understanding.

GOAL#2: Core Transformer Configuration Matrix

This effort began with an investigation into different attributes related to kVA sizing, critical design specifications and accessories. The input provides insight to Utilities and Manufacturers on what the broader peer groups are doing in their individual systems or regions. This could be used to identify transformer sizes or features that can be consolidated or phased out due to increased standardization or electrification in the system. The impact of reducing variations could increase the economies of scale for increased manufacturing efficiency while providing the potential for more streamlined inventory to support areas of mutual assistance. This information led to the creation of specific configurations to identify the minimal components to safely operate as compared to a standard baseline and ultimately the utility customized configuration. The impact of these configurations was reviewed by manufacturers to identify the impact to the manufacturing process and opportunities for increased manufacturing capacity. This document was designed to be used as a starting point by utilities for new transformers to understand each configuration needs and the impact to manufacturing time and complexity that result in tradeoffs of ideal functionality and manufacturing throughput. Using this information for new designs could help decrease the manufacturing time per unit and avoid some critical long lead time components resulting in an increase of overall transformer manufacturing capacity.

GOAL #3: Interchangeability Matrix

Many supply chain influences have been identified throughout this process of defining critical features and configurations which result in significant impacts to the overall lead time. This may be due to sole source vendors, production limitations by preferred vendors, incompatible specifications, or many other factors. Not all utilities and even manufacturers may understand the breadth of the supply chain landscape to understand all the potential vendors available for these critical products. This table provides the opportunity to leverage inputs from multiple transformer manufactures and utilities to identify potential alternatives for compatible or completely interchangeable critical components. This is not an outline of preferred manufacturers, but rather an insight from the broader peer groups as to manufacturing options. This document is intended to be used as a tool to provide more informed and efficient discussions between manufacturers and utilities to support consistent supply of critical components and faster acceptance for identified interchangeable components. This matrix could also be used by manufacturers to proactively work with utilities to approve alternate vendors identified in the matrix to optimize the lead times based on component availability. Utilities could further use these references to leverage a larger knowledge database for critical interchangeability of areas such as fuses to identify alternatives and proper coordination.

Deliverable #2: Broader input request for Configuration Matrix

Transformer Attribute Consolidation background information provided:

Attribute Consolidation designed to identify the most prevalent transformer kVA sizing requested by the utilities as well as opportunities for consolidating for both sizing and selected attributes to minimize the number of transformer variations and streamline the manufacturing process. These opportunities could be the result of electrification which may increase the minimum transformer size from 10/15kVA to 25/50kVA. This was also expanded to rate critical options and accessories along with the potential for aftermarket installation at the utility.

Action:

1. The ask was identification of these sizes, options and accessories rated on a Red/Yellow/Green scale to identify the high running critical sizes and specifications that should be kept or not altered (RED), standard volume with flexibility in functionality or specification that could be altered if broadly agreed (YELLOW), and sizes and specifications that could be removed or exchanged relatively simply (GREEN).
2. Review of the Summary action points in conjunction with any additional input provided above for comments, concerns, and suggestions.

kVA Sizing and Frequency

1P pole top	Utility 1	1P Pad	Utility 1	3P pad	Utility 1	Network	Utility 1	3P Vault/ Submersible	Utility 1
.5 (1440)		10 (360)		45		333		300	
1 (1440)		15 (360)		75		500		500	
1.5 (1440)		25		112.5		750		750	
3 (1440)		37.5		150		1000		1000	
5 (1440)		50		225		1500		1500	
10 (1440)		75		250		2000		2500	
15 (1440)		100		300		2500		3325	
25 (1440)		167		500		100 (1ph)			
37.5 (1440)		250		750		167 (1ph)		Submersible (1ph)	Utility 1
50				1000		300 (3ph)		15	
75				1500				25	
100				2000				37.5	
167				2500				50	
250				3000				75	
333				3750				100	
500				5000				167	
750				7500				250	

BIL Rating and Ranges

1P pole top/3P pole top/ 1P pad/ 3P pad/ Network	BIL rating	Utility 1
2.4	45	
4.16		
4.8	60	
6.9		
7.2		
7.62	75	
7.97		
8.32		
12		
12.47		
13.2	95,110	
13.8		
14.4		
19.9		
22.86	125,150	
23		
24.94		
20.8	125,150,200	
34.5		

Protection

1P pole top	Utility 1	3P pole top	Utility 1	1P Pad	Utility 1	3P pad	Utility 1	Network	Utility 1
Conventional		Conventional		Conventional		Conventional		Conventional	
Completely Self Protected		Completely Self Protected		FUSED		Fused/Fault Interrupter		Fused	

Bushing Class

1P pole top*	Utility 1
A	
B-1	
B-2	
B-3	

Configuration Matrix and Manufacturer Input to Configuration Matrix

There were several topics identified from the attribute consolidation that required some further refinement on the possible actions that might be considered to support the target goal of increasing the number of transformers that could be manufactured while maintaining the necessary operation and specifications for the utilities. To provide more insight to both the utilities and manufacturers, the Configuration Matrix was developed to help understand what functions and components were necessary for three different configurations:

- Minimalist Configuration: absolute minimum components to safely operate a transformer.
- Standard Configuration: which included minimalist with more streamlined components to ensure full IEEE standard compliance and baseline operation.
- Custom Utility Configuration: fully customizable to each utility specification including component locations, alternate protections, paint/branding, and specific regional requirements.

Manufacturer Input to Configuration Matrix: Once these configurations were defined, the manufacturers were asked to provide input on their impact to manufacturing time to understand the potential impact to increasing the number of deliverable units. This break down is primarily focused on labor, impacts to design, and improved scaling in the factory. The impact of supply chain on the timeline and availability were not the primary focus due to variability among manufacturers though comments are included.

Action:

1. Review and comment on the Configuration categories as described in the following tables or in the accompanying Excel file. The configurations are represented in the three columns so if a component or function is needed for more than one configuration the columns are merged accordingly to show that. Please feel free to mark changes or comments in RED directly in the document or in a column just off to the side. There are separate tabs for single phase overhead, single phase pad mount, and three phase pad mounts.
2. Review and comment on input from the manufacturers on the impact of the different configurations mostly targeted to manufacturing labor/scheduling impacts. The impact of supply chain was not accounted for in the percent labor as this is quite variable, but there are some related comments directly addressed.

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Overhead		
Mild Steel Tank with IEEE C57.12.28 Coating System		
	ANSI #24 (dark gray) or ANSI #70 (light gray) paint. Coating system to meet IEEE	
		Stainless Steel Tank and/or covers (Grades 304 or 409)
No Switches on LV or HV		
	Dual Voltage switch standard 2:1 ratio	
	Optional Taps in HV winding, 2 above and 2 below, of 2.5%	
		4 Position Switches
No fusing or Secondary breaker protection		
		Current Limiting Fuse
		CSP units with LV Breaker
		HV breaker (Magnex)
		Secondary circuit breaker protection with indictor light (CSP transformer)
		Expulsion fuse in HV
		Under Oil Arresters
		Lightning arresters & mounting bracket
		Lightning Mitigation Design Considerations
		Custom fuses in terminal board in HV
Single Cooling rating 65°C AWR		
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
Fluid - mineral oil		
	Dielectric Fluids -- Mineral Oil or Esters	
Standard Impedance as per DOE		
	Minimum Impedance as per IEEE Stds.	
		Required Impedance Ranges
Single Hanger Mounting		
	Single or Double Hanger Mounting	
		Two sets of support lugs (RUS spec.)
Primary Bushing Rated for System Voltage		
	1 or 2 bushings in HV, 3 or 4 bushings in LV, livefront type	
		Secondary terminations
		Primary Bushing Creep Distance
Standard pressure-relief system (PRV)		
	Cover grounding connection	
	Tank grounding connector (accepts #8 to #2 AWG conductor)	
		Internal Fault Detector
		Vacuum Pressure Gauge
		15kV Insulated covers
		Wildlife protection
		Special BIL requirements in HV
Nameplate		
	Standard Nameplate on support lug	
		Labeling / Branding Requirements
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount
Mild Steel Tank with IEEE C57.12.28 Coating System		
Tank and compartment with doors to prevent access to terminals and connections		
	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	
		Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
		300 stainless steel sill
		Special spacing and locations of components on front tank wall
		Special colors (Gray ANSI 70, Desert Tan)
		Deeper Cabinet
		Footprint Requirements
No Switches on LV or HV		
No taps in HV winding		
	Radial or Loop feed terminal arrangement	
		Dual Voltage switch standard 2:1 or 3:1 ratios
		Tap changer ((2) +/- 2.5% taps)
		Tap Changers (5 position, 7 Position)
		DeEnergized Tap Changer
		Loadbreak ON/OFF switch
		Sectionalizing loadbreak switches
		4160x12kV Primary
Bayonet Fusing with Isolation Link		
	Protection (Bay-o-nets/ELSP)	
		Protection -- Magnex Breakers
		LV in Line Terminals mounted on LV bushing studs
		Lightning arrester attachment
		Secondary Arrester -- Internal/External MOV
		Secondary connectors (zbars, covered/not covered)
		HV fusing with general purpose partial range current limiting fuse, internally mounted
		19.9kV Under Oil Arresters
		Special fusing with full range current limiting fuse with cannister fuse holder
		Custom fuses in terminal board in HV
Primary bushing arrangement - standard per IEEE - TYPE 2 A		
Seconary bushing arrangement - standard per IEEE - TYPE 2 A		
	Primary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
	Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
		Specific Bushing Layout
		Loop fed (2 primary bushings)
		Preapproved bushing inserts.

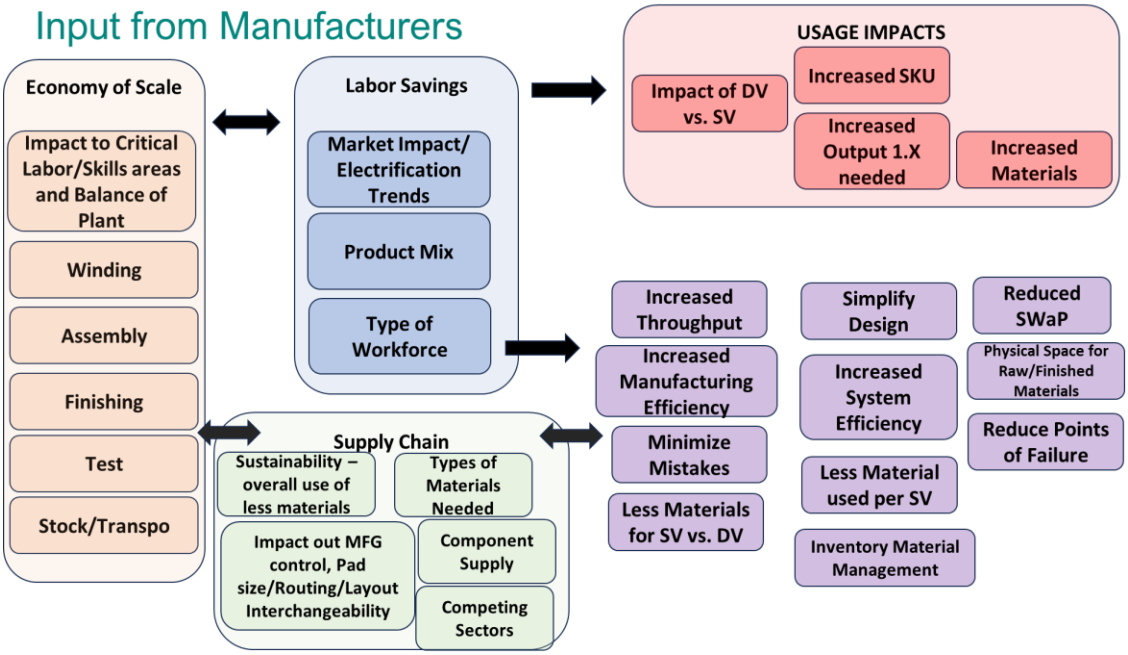
Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
Single Cooling rating 65°C AWR		
Fluid - mineral oil		
		Fluid (Ester)
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
Minimum BIL ratings		
Standard Impedance as per DOE		
	Compliance with BIL and Dielectric Test Requirements	
	Minimum Impedance as per IEEE Stds.	
		Special BIL requirements in HV
Pressure relief valve		
Nameplate		
	Oil fill provision - standard per IEEE	
	Oil drain provision - standard per IEEE	
	Lifting provisions	
	LV ground connector and/or connection	
	Parking stands in HV compartment	
	Ground connector in tank	
		Internal Fault Detector
		provisions for a 9/16" dia padlock. Hex bolts for securing bolts
		Clearance and Warning stickers per Company design
		Copper Oxide on door latch hardware
		Vacuum Pressure Gauge
		Ground Clamps
		Drain valve with sampling
		Plastic Drip shield for Bayonet
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		Thermometer
		Liquid Level Gauge

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Mild Steel Tank with IEEE C57.12.28 Coating System		
Sealed tank construction with welded cover and bolted handhole		
Tank and compartment with doors to prevent access to terminals and connections		
	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	
	Coating system to meet IEEE, Green color	
	Terminal arrangement as per compartment configuration of IEEE Stds.	
		Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
		Special spacing and locations of components on front tank wall
		HV compartment on the left, LV compartment on the right. HV compartment can't be opened without opening the LV compartment
		HV and LV compartments seperated by a barrier of metal or other rigid material
		Special spacing and locations of components on front tank wall
		Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
		Special colors (Gray ANSI 70, Desert Tan)
		Custom Mechanical structures (Ducts, flanges, Throaths) for HV or LV connections
Primary feed - radial		
Single voltage primary (no Dual Voltage)		
No taps		
No Switches on LV or HV		
Full Capacity Windings HV and LV		
Standard neutral configuration per IEEE		
	Radial or Loop feed arrangement in HV	
	DE-energized tap changer with external operation	
		Dual Voltage switch standard 2:1 or 3:1 ratios
		Tap changer ((2) +/- 2.5% taps)
		Netural options
		ON/OFF loadbreak switches
		Sectionalizing loadbreak switches
		5 legged design or 3 separate core assemblies
		Eaton 4 position switch on primary side to de-energize transformer without "bliping" downstream customers.
		4160x12kV Primary
		Tap Changers (5 position, 7 Position)
		K Factor (Design for Loads with high harmonic content)
No fusing or Secondary breaker protection		
	Bayonet fusing and isolation link	
		HV fusing with general purpose partial range current limiting fuse, internally mounted
		Internal fusing
		VFI for 2000kVA and up
		Coil switch (on/off)
		4 Position Switches
		Special fusing with full range current limiting fuse with cannister fuse holder
		Arresters
		Under Oil Arresters
		Secondary Arrester -- Internal/External MOV

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
3 Phase Pad		
Secondary termination - Live front spade connectors		
Seconary bushing arrangement - standard per IEEE		
Primary termination - 35 kV, 200 amp bushing wells		
No inserts		
Deadfront bushings in HV		
Livefront bushings in LV		
	Primary termination - 35 kV, 200 amp bushing wells	
	No inserts	
	Primary bushing arrangement - standard per IEEE (specific dimensions)	
	Secondary termination - Live front spade connectors	
	Seconary bushing arrangement - standard per IEEE (specific dimensions)	
		Specific Bushing Layout
		Custom spade terminals mounted on LV bushings and mechanically supported
		12-hole NEMA pads for secondary connectors
		Supplied with Primary bushings.
		Preapproved bushing inserts.
		Special LV terminals with number of holes above IEEE Stds., and customized mechanical support structures
Standard Impedance as per DOE		
Minimum BIL		
Single Cooling rating 65°C AWR		
		95kV BIL for 15kV, 150kV BIL for 35kV units
		Impedance requirements
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
Fluid - mineral oil		
		Fluid Mineral Oil or Ester
Nameplate		
	Standard Danger and Warning Safety Labels - NEMA 260	
		Manufacturered after 1979 sticker
		Clearance and Warning stickers per Company design
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		Branding requirements

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
3 Phase Pad		
Oil fill provision - standard per IEEE		
Oil drain provision - standard per IEEE		
No gauges		
	Ground connector in tank	
	Jacking facilities for lifting	
	Parking stands in HV compartment	
	Standard pressure-relief system (PRV)	
		Copper Oxide on door latch hardware
		Vacuum Pressure Gauge
		Drain valve with sampling
		Temperature Gauge
		Internal Fault Detector
		Liquid Level Gauge
		provisions for a 9/16" dia padlock. Hex bolts for securing bolts
		Solid Insulation
		Plastic Drip shield for Bayonet

Input from Manufacturers on impacts to Labor only						
	Minimalist Configuration	Opportunities for Scarle or Automation Improvement	Standard Configuration (+% labor hours)	Opportunities for Scarle or Automation Improvement	Custom Utility Specific Configuration	Opportunities for Scarle or Automation Improvement
Single Phase Overhead	Baseline	No taps vs Taps ((2) +/- 2.5%)	4%			
Single Phase Pad	Baseline	No taps vs Taps ((2) +/- 2.5%)	4%			
Single Phase Overhead	Baseline	Single Voltage HV			Dual Voltage in HV	6%
Single Phase Pad	Baseline	Single Voltage HV			Dual Voltage in HV	6%
Single Phase Overhead	Baseline	No switches LV or HV			CSP units with LV Breaker or HV breaker (Magnex)	7%
Single Phase Pad	Baseline	No Switches on LV or HV			HV fusing with general purpose partial range current limiting fuse, internally mounted	4%
Single Phase Pad	Baseline	No Switches on LV or HV			Special fusing with full range current limiting fuse with cannister fuse holder	5%
Single Phase Pad	Baseline	Bayonet Fusing with Isolation Link	2%			
Single Phase Pad	Baseline	No Switches on LV or HV			Loadbreak ON/OFF switch	2%
Single Phase Overhead	Baseline	No arrester			Under Oil Arresters	3%
Single Phase Pad	Baseline	No arrester			Under Oil Arresters	3%
Single Phase Overhead	Baseline	No arrester			Lightning arresters & mounting bracket	1%
Single Phase Overhead	Baseline	No Special Markings			Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)	0.5%
Single Phase Pad	Baseline	No Special Markings			Custom markings (decals or stencils: Non PCB, warning/danger, Customer ID numbers, Barcode Labels)	1%
Single Phase Pad	Baseline	No Gauges			Thermometer and Liquid Level Gauge	3%
Three Phase Pad	Baseline	Standard padmount green paint color			Special colors (Gray ANSI 70, Desert Tan)	2%
Three Phase Pad	Baseline	Mild Steel Tank with IEEE C57.12.28 Coating System			Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	2%
Three Phase Pad	Baseline	Mild Steel Tank with IEEE C57.12.28 Coating System			Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	2%
Three Phase Pad	Baseline	Terminal arrangement as per compartment configuration of IEEE Stds.			Special spacing and locations of components on front tank wall	2%
Three Phase Pad	Baseline	No taps vs Taps ((2) +/- 2.5%)	3%			
Three Phase Pad	Baseline	Single voltage primary (no Dual Voltage)			Dual Voltage Primary	7%
Three Phase Pad	Baseline	No fusing or Secondary breaker protection			HV fusing with general purpose partial range current limiting fuse, internally mounted	3%
Three Phase Pad	Baseline	No fusing or Secondary breaker protection			Special fusing with full range current limiting fuse with cannister fuse holder	5%
Three Phase Pad	Baseline	Mild Steel Tank with IEEE C57.12.28 Coating System			Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	4%
Three Phase Pad	Baseline	Mild Steel Tank with IEEE C57.12.28 Coating System			Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	4%
Three Phase Pad	Baseline	No Switches on LV or HV			ON/OFF loadbreak switches	2%



Deliverable #3: Broader input request for Interchangeability Matrix

Interchangeability Matrix background information provided:

The target of the interchangeability matrix was to provide a listing of critical components that impact the delivery, capacity, or other supply chain impacts. This listing is compiled from input by multiple manufacturers and utilities to provide a broad range of knowledge of standard and suitable alternative suppliers for specific components. In some cases, there are many potential suppliers for a particular component, all manufacturers or utilities may not have a working relationship or have had the need to engage multiple suppliers in the past, so this consolidated listing is meant to provide a starting point for this discussion. This is meant to be a dynamic list to be updated as new vendors, components, or general information becomes available so the input from the broader engineering community is vital to ensure current information. The spreadsheet has a main working tab with all the current inputs with a sortable pull-down menu for each category. To provide more targeted details, there are additional tabs that contain specific categories for quicker reference whether that be fuses, bushing, or other distinct items.

Action:

1. Review and comment on the Interchangeability Matrix as described in the accompanying Excel file or provide input on critical components in the following table. Please comment or make additions in RED text so that we can consolidate all incoming input. If there are components that are not listed that you would like to have added, please make those additions with whatever information that you have available (i.e. you may not have multiple vendors or part numbers, but please input what you do have so that we can get further input from other sources.)
2. Comment on what additional information you think would be helpful in this document to provide sufficient details to proactively coordinate between manufacturers and utilities on what components can be considered interchangeable.
3. Comment on most requested substitutions as well as primary requirements or roadblocks to substitutions.

	Utility Solicited Comments
Critical Components and Accessories	Comments
Protection -- Bayonet Fuses	
Protection -- Current Limiting	
Bayonet Assembly or Fuse Holders	
Protection -- Isolation links	
Protection -- Magnex Breakers & LV Breakers	
Protection -- Fuse Cartridge	
Primary Arresters -- Normal Duty/Heavy Duty	
Primary Arresters -- Under Oil	
Secondary Arrester -- Internal/External MOV	
Tap Changers (5 position, 7 Position)	
Dual Voltage Switches	
4 Position Switches	
LBOR Switches	
High Voltage Bushings	
Low Voltage Neutral Bushings	
Bushing Wells	
15kV Insulated covers	
Stainless Steel Tank/Hardware	
Internal Fault Detector	
Pressure Relief Valves	
Oil Level Indicators	
Dielectric Fluids -- Mineral Oil or Esters	

	Utility Solicited Comments
Critical Components and Accessories	Comments
Solid Insulation	
Grounding Clamps	
Animal guards	
Creep Bushings	
Vacuum Pressure Gauge	
Drain valve with sampling	
Temperature Gauge	

Summary Information/Action Points	**Agree**	**Disagree**	**Comments**
Consolidate to 1.5kVA Sizing to support all specifications for control/instrumentation			
Elimination of 3-15kVA (possibly up to 25kVA) single phase overhead variations due to increased electrification. Shift of the low-end sizing to accommodate electrification so starting with 25kVA, 50kVA, or 75kVA units.			
Standardization of labeling, stenciling, and placement for manufacturing efficiency			
Eliminate the consideration for CSPs as standard product			
Consideration for elimination of Dual Voltage transformers			

Summary Information/Action Points	Agree	Disagree	Comments
Tradeoff for Dual Voltage designs on the efficiency (as sizing is focused on the worst-case operation)			
Tradeoff impact of Dual Voltage on space utilization, sizing, and overall material usage			
Increased opportunity for failure due to higher number of components and complexity of manufacture with high voltage and low voltage switches			
Overall reduction to the number of SKUs in the system for Dual Voltage vs. Single Voltage			
Primary driver for Dual Voltage is to support future upgrades across the system			
Consider limiting Dual Voltage transformers to specific voltage ratios for simpler manufacturing			
Limiting the use of Tap changers to standard values only			
Support standardization of front plate interconnections (bushing size, spacing, fuse placement, etc.) for pad mounts to improve production and interchangeability			
Elimination of under oil arrestors			
Agreement to work between Utilities and Manufacturers to continue to Develop the Interchangeability Matrix.			
Do you see the Interchangeability Matrix as a proactive tool to help Manufacturers navigate the changing Supply Chain issues?			

Summary Information/Action Points	Agree	Disagree	Comments
Would a fuse database be a helpful reference to support interchangeability of potential fuse vendors?			
Are there specific vendors or components that your Utility would not consider in the Interchangeability matrix?			