Distribution Service Transformer Sub-Group on Standardization Opportunities

Combined Content
from Working Meetings

DT convening group goals

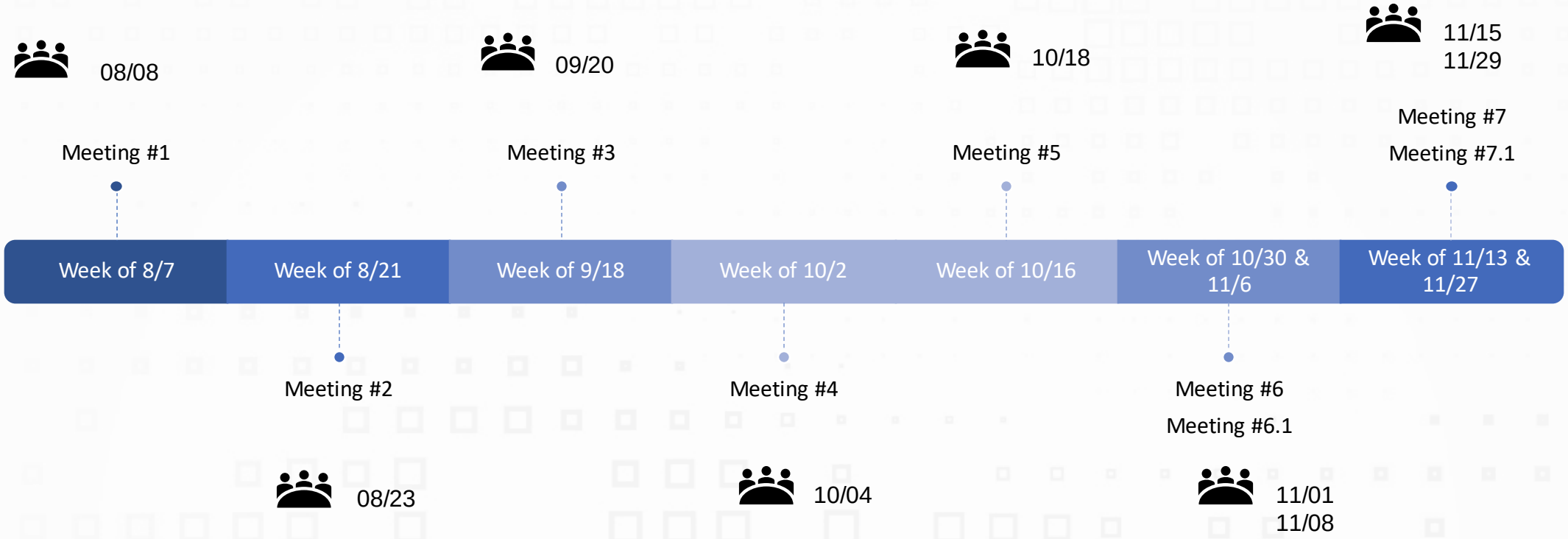
Short Term Goals

- 1. Create a distribution transformer taxonomy- this is to ensure that not only everyone in this group is on the same page, but that we could share with manufacturers and other stakeholders so that we are all speaking the same language.
- 2. Create a core transformer configuration list: This would be broken down into three categories
  - a. Red- spec to keep or to not be altered
  - b. Yellow- spec not functionally necessary but will require an organizational acceptance or can be altered
  - c. Green- spec can be removed or can be exchanged
- 3. Development of the interchangeability matrix

Long Term Goals

- 4. R&D on flexible transformers- Use these discussions to inform R&D on flexible transformers, that could be used interchangeably in the event of extreme weather etc.
- 5. Procurement strategies- Collectively identify enhancements to existing planning and procurement processes necessitated by the emergence of supply chain constraints.

Project Timeline (Separate Utility and Manufacturer Meetings)



Meeting

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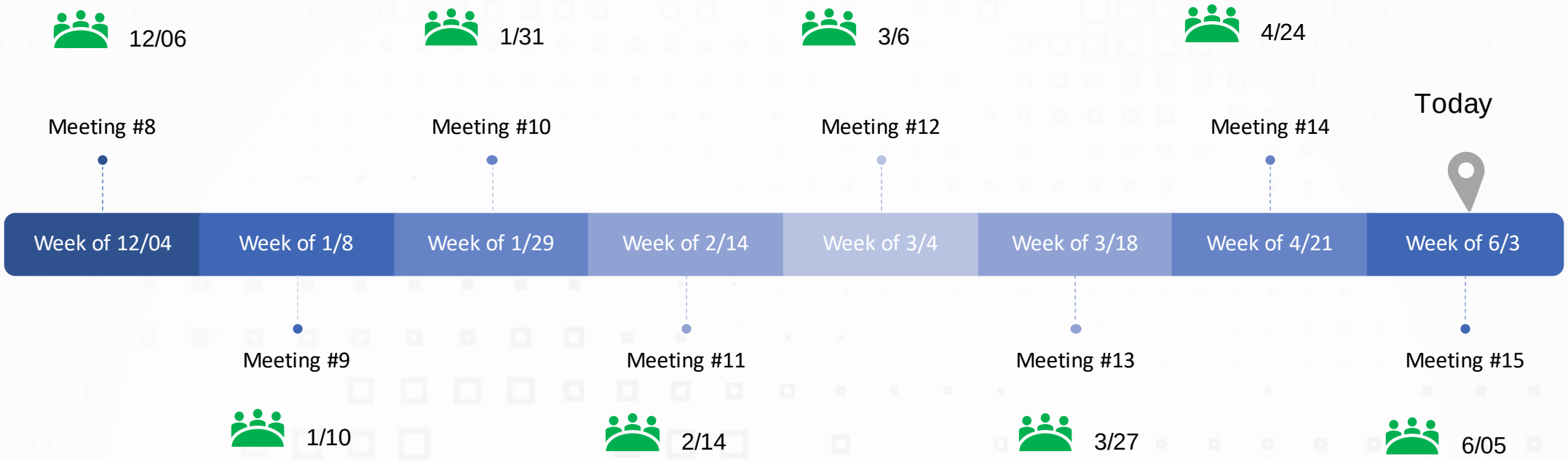
Project Timeline (Combined Utility and Manufacturer Meetings)



Meeting

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Consolidated Working Documents from Meetings 1-8

Goal1: Taxonomy

Taxonomy related to critical design parameters or components

- Information based on IEEE, Convening input, and supporting documents:

Design Attributes			Comments
	Impedance	Percentage	
	Total Ownership Cost (TOC)	A and B Factors	
	Average Winding Temperature	65°C/75°C/Dual Rating	
	Capacity Factor		
	Physical Size/Weight		
	Cable Entrance Openings		
	Jack Bosses		Used on pads to insert fork lifts to move units around.
	Lifting Lugs/Provisions		Used for lifting pad mount transformers with rigging.
	Paint/Color	Pretreatment requirements, paint color	Specify pretreating the exterior before painting (after consulting with EPRI) and paint color. We use Munsel Green 7.0 GY3.29/1.5 for pads and ANSI 24 or 70 for OH tubs
	Nameplate material	Material Specifications	Stainless Steel, etc.
	Bracket Positions		IEEE specifies for OH transformers the spacing and configuration of pole mounting brackets.
Windings/Coil			
	Materials	Copper/Aluminum/Alloys	
	High Voltage/Low Voltage	Sizing requirements, I^2R losses,	
	Winding Configuration	Delta-Wye, Wye-Wye, etc.	
	Thermal Relay		
	Phasing	Single phase, Three phase	
Insulation system			
	Solid Insulation Materials	Cellulose base	
	Mineral Oil	(inhibited/uninhibited)	
	Ester	Natural/Synthetic	
	Class 105 (A)	Materials or combinations of materials, which by experience or accepted tests, have been shown to give the required life at a continuous temperature of X°C.	
	Class 130 (B)		
	Class 155 (F)		
	Class 180 (H)		
	Class 220 (>H)		
	Class over-220		
Transformer core			
	Materials	Core losses, Form factor,	
	Material Grade		
	Core design	triplex	
Oil Tank/Housing			
	Materials	Corrosion resistance	
	Temperature detector		
	Pressure Relief device	PRV vs. alternate methods	
	Sampling Valve		
Tap Changer			
	Load Tap Changer	A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load. Syn: onload tap-changer (IEC 50).	
	De-energized Tap Changer	A selector switch device used to change transformer tapswith the transformer de-energized.	
	4 Position Switch	Used on loop fed, 3 ph transformers to de-energize transformer or turn off feeds (HXA or HXB) or have them all energized.	

Cooling System			
	Oil	Miral Oil, (inhibited/uninhibited), Ester (natural/synthetic)	
	Dry		
	FM Approved		
	Radiator		
	Cooling Classification	Natural/Forced/Liquid/Surfaces	
Protection			
	Conventional vs. CSP		
	Basic Impulse Level		
	Bushing Class		
	Arrestors		
Terminals and Bushings			
	Bushing Well/Bushing Clamp/Bushing Insert		
	Bushing Sizing		
	Dead front	200A Loadbreak	Could be a 600A T with bushing well
	Live front	600/900A Deadbreak	Bushings are exposed
	Padmount Spade Bushings	Hole count 4-24, Universal spacing	
	Single Phase	Studs	
	Grounding Tabs/Drain Wire		
	Insulated Parking Bushing		
	Radial or Loop Fed		Padmounts can be radial (H1 1ph, H1, H2, H3 3ph) or loop fed (H1A, H1B, 1ph, H1A, H1B, H2A, H2B, H3A, H3B, 3ph)
	Bushing numbers		1ph OH transformers can be 1 or 2 bushing design
	Neutral grounding		Generally, we specify the X2 bushing to be bonded with a ground strap to the tank on all transformers.
	Removable Ground connection between H0 and X0		For pad mount 3ph wye-wye banks we require a switch that will open/close a connection between H0 and X0 for testing purposes.
Fusing			
	Current-limiting Type	A fuse that, when it is melted by a current within its specified current-limiting range, abruptly introduces a high arc voltage to reduce the current magnitude and duration.	
	Expulsion Type	Expulsion fuses ultilize gas and vapor mechanism to limit the duration of the current, but does not decrease its magnitude.	
	Bayonet Style		
	Bushing Style		
	Terminal Board Style		
	Isolation Link		
	Fuse Cutout		
	Protection curves		
	Protection Limits		
	Internal Fault Detection Sensor		
	Magnex Breaker		Used on 1ph pad mount transformers for protection. Is a Cooper only product as far as I know.
	Secondary Breaker		Used on OH CSP tubs.
	Dry Canister w/ NX fuses		Used on older models. Is a dry (IE fuse isn't oil embedded) and uses NX style fuses.

Goal 2: Core transformer configuration list

Transformer attribute consolidation

Initial List of DT attributes

Attribute	Example
Type	Overhead, Pad Mount, Network
Size	KVA rating for the transformer (0.5 kVA to 2,500 kVA)
High Side Voltage	High side operating voltage (2.4 kV to 34.5 kV)
Low Side Voltage	Low side operating voltage (208 to 600V)
Phasing	Single phase, Three phase
Protection	Conventional vs. CSP, Applicable to OH transf. only
Winding Configuration	Delta-Wye, Wye-Wye, etc.
Cooling System	Oil, Dry
Basic Impulse Level	BIL level tied to voltage class
Bushing Class	Outlines number of bushings and configuration, arrestors, etc. Applicable for overhead transformers

Focused List of DT attributes

Attribute	Example
Size	KVA rating for the transformer (0.5 kVA to 2,500 kVA)
High Side Voltage	High side operating voltage (2.4 kV to 34.5 kV)
Protection	Conventional vs. CSP, Applicable to OH transf. only
Basic Impulse Level	BIL level tied to voltage class
Bushing Class	Outlines number of bushings and configuration, arrestors, etc. Applicable for overhead transformers

- **Red** – spec to keep
- **Yellow** – spec not functionally necessary but will require an organizational acceptance
- **Green** – spec can be removed

Summary points – Attribute Consolidation

- Flexibility on control/instrumentation sizing (0.5-1.5kVA)
  - Point that an SST may be considered
  - What is largest size that can mount to capacitor rack (size impact of 0.5 to 1.5)?
- Standardizing to Larger KVA Transformers
  - May be able to eliminate 3-15kVA 1ph OH due to electrification
  - For different kVA Classes -- May need a tap to cover some of yellow marked ranges
  - Could result in higher losses/lower efficiency, physical size, cost, heat losses, impact on 3 phase bank solutions
  - Evaluate change in construction specs (pole size, pad size, line crew)
  - Need to develop Cost benefit analysis
- Concern with increasing BIL rating
  - Result in greater spacing requirements, larger bushings, larger cabinets
  - Negative impact to cost
  - Change in construction specs (pole class, pad size, etc.)
- Bushing Class
  - Versatility of 1ph and 3ph banks with two bushing design
  - Impact to rest of distribution system
  - B-2 needed for CSPs and small equipment sizes
- 3ph Pad mounts
  - Primary taps 7 position vs. 5 position for wider voltage ranges
  - Are the tap changers readily available in both configurations and impact to cost?
- Standardization of labeling and stenciling on transformers for Manufacturing efficiency
  - Some industry initiatives may already be started (EPRI?).
- NOTE: 250kVA 1ph Pad utilized for EV charging frequently in new installs over traditional 100/167kVA options
- Standardization of protection requirements and curves
- Opportunities to reduce areas of CSPs or 3ph pole top

Action points – Attribute Consolidation

- Agreement to settle on 1.5kVA to support all specifications for control/instrumentation sizing (0.5-1.5kVA) (What is maximum kVA value in this case size?)
- Agreement to eliminate 3-15kVA 1ph OH variations – Start evaluation with 25kVA 1 Ph OH
  - Evaluate impacts such as higher losses/lower efficiency, physical size, cost, heat losses
  - Evaluate change in construction specs (pole size, pad size, line crew)
  - Need to develop Cost benefit analysis
- 3ph Pad mounts
  - Evaluate impact of primary taps – 7 position vs. 5 position for wider voltage ranges
  - Are the tap changers readily available in both configurations and impact to cost?
- Standardization of labeling and stenciling on transformers for Manufacturing efficiency
- Standardization of protection curve requirements
- Eliminate consideration for CSPs or 3ph pole top?
- Concern with increasing BIL rating
  - Result in greater spacing requirements, larger bushings, larger cabinets
  - Negative impact to cost
  - Change in construction specs (pole class, pad size, etc.)

Transformer attribute consolidation (Background Utility Work)

Instructions Provided to Utility Workgroup Members

- Please add any missing attribute data
  - Ex. If for 3P pole top you see a KVA # missing you can add a new row to make the addition or add it at the end.
- Use the following colors to classify the attributes in the categories below:
- **Red** – spec to keep or to not be altered
- **Yellow** – - spec not functionally necessary but will require an organizational acceptance or can be altered
- **Green** – spec can be removed or can be exchanged

Overhead 1P/3P kVA Sizing and Frequency

1P pole top	Utility 1	Utility 2	Utility 3	Utility 4
.5 (1440)				
1 (1440)				
1.5 (1440)				
3 (1440)				
5 (1440)				
10 (1440)				
15 (1440)				
25 (1440)				
37.5 (1440)				
50				
75				
100				
167				
250				
333				
500				
750				

	No 3ph OH	No 3ph OH		Not use 3ph but 3 single phase in bank
3P pole top	Utility 1	Utility 2	Utility 3	Utility 4
10 (2340)				
15 (2340)				
25 (2340)				
37.5 (2340)				
50				
75				
100				
167				
250				
333				
500				
750				

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Pad Mount 1P/3P kVA Sizing and Frequency

1P Pad	Utility 1	Utility 2	Utility 3	Utility 4
10 (360)				
15 (360)				
25				
37.5				
50				
75				
100				
167				
250				

3P pad	Utility 1	Utility 2	Utility 3	Utility 4
45				
75				
112.5				
150				
225				
250				
300				
500				
750				
1000				
1500				
2000				
2500				
3000				
3750				
5000				
7500				
3750				

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Network/Submersible 1P/3P kVA Sizing and Frequency

				Do not use network Transformers
Network	Utility 1	Utility 2	Utility 3	Utility 4
333				
500			3ph	
750			3ph	
1000			3ph	
1500			3ph	
2000			3ph	
2500			3ph	
100 (1ph)			1ph	
167 (1ph)			1 ph	
300 (3ph)			1ph	

3P Vault/Submersible	Utility 1	Utility 2	Utility 3
300			
500			
750			
1000			
1500			
2500			
3325			
Submersible (1ph)			
15			
25			
37.5			
50			
75			
100			
167			
250			

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Protection Requirements

1P pole top	Utility 1	Utility 2	Utility 3	Utility 4
Conventional				
Completely Self Protected				

1P Pad	Utility 1	Utility 2	Utility 3	Utility 4
Conventional				
FUSED				

3P pole top	Utility 1	Utility 2	Utility 3	Utility 4
Conventional				
Completely Self Protected				

3P pad	Utility 1	Utility 2	Utility 3	Utility 4
Conventional				
Fused/Fault Interrupter				

Network	Utility 1	Utility 2	Utility 3	Utility 4
Conventional				
Fused				

BIL Requirements and Flexibility

BIL	1P pole top/3P pole top/ 1P pad/ 3P pad/ Network	BIL rating	Utility 1	Utility 2	Utility 3	Utility 4
	2.4	45			45	45
	4.16	60		60	60	
	4.8				60	60
	6.9			60		
	7.2	75				
	7.62				75	75
	7.97					
	8.32					
	12	95,110		95		
	12.47					
	13.2				110	95
	13.8				95/110	110
	14.4				95/110	
	19.9	125,150			125/150	
	22.86					125, 150
	23					
	24.94	125,150,200				125, 150
	20.8			125		200
	34.5				150/200	

Bushing Class	1P pole top*	Utility 1	Utility 2	Utility 3	Utility 4
	A				
	B-1				
	B-2				
	B-3				

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Identify additional Critical Design Specifications – that impact internal design and number of SKUs not already captured

Overhead transformer options and accessories

Option or Accessory	Potential for "Aftermarket Installation"
Taps either two 2.5% above and below; four 2.5% below, NEMA taps or special taps	No
Externally operable tap changer switches for safe operation	No
High corrosion area protection with 304 or 409 stainless steel hardware and tanks	No – Note most rust on cover so consider Lid/Ring as stainless, Mild steel tank
MagneX™ interrupter	No
Birdguards	Yes
Envirotemp™ FR3™ fluid where less-flammable fluid is required, and superior environmental characteristics are desired	Yes -- May not make sense from aftermarket and who takes responsibility for oil management. May reduce clearance requirements for commercial/residential
Cover with a minimum dielectric strength of 15 kV	No
Extra creep high voltage bushings (up to 150 kV BIL)	No
Porcelain low-voltage bushings	No
Canadian Standards Association (CSA) conforming design	No – Need to look at IEEE vs. CSA, some manufacturers/utilities may need both
Special designs conforming to international specifications	No
Drain/sampling valve	Yes
Pressure vacuum gauge (tank size limitations apply)	Yes
Filter press connections	No
Temperature gauge (tank size limitations apply)	Yes
Liquid level gauge (tank size limitations apply)	Yes
High efficiency transformers at 0.05% or higher above DOE efficiency	No

Overhead transformer options and accessories (continued)

Option or Accessory	Potential for "Aftermarket Installation"
Secondary breaker with weak link for secondary fault and overload protection (RED for CSP)	No
Primary weak link fuse	No
Current limiting fuse for high interrupting ratings and limiting fault currents	No
Low-voltage distribution class MOV arrester – internally or externally mounted	No
Lightning arresters for primary over-voltage protection: direct connected, normal or heavy duty metal oxide varistor (MOV) internal	No
Lightning arresters for primary over-voltage protection: direct connected, normal or heavy duty metal oxide varistor (MOV) external	Yes
High voltage bushing location - cover mounted or side wall mounted	No – Mostly cover mounted, some older side mounted
Dual voltage switch	No
Stainless steel tank	No
Primary Termination – cover mounted or side wall mounted	No
Secondary Termination – Porcelain vs. polymer bushings	No
Primary Switching – externally operated tap changer, dual voltage switch or terminal board	Yes
Overcurrent Protection – internally mounted current limiting fuse in series with protective link	Yes

Pad mounted transformer options and accessories

Option or Accessory	Potential for "Aftermarket Installation"
Various multiple voltages or taps	No
Externally-operable multiple voltage or tap changer switches for safe operation	No
Stainless steel tank, tank bottom, sill, door, and/or hardware	No
Service entrance in sill	No
Various spades and terminals available for secondary bushings	Yes
High efficiency transformers at 0.05% above DOE efficiency or higher	No
Stenciled bushing designations	No
High-voltage bushing inserts	No
Ground connectors	Yes
Captive stainless steel hexhead door locking bolt	Yes
RUS design	No

Pad mounted transformer options (continued)

Option or Accessory	Potential for "Aftermarket Installation"
One piece high-voltage bushings	No
High-voltage bushing wells with removable studs	No
Envirotemp™ FR3™ fluid	Yes
Canadian Standards Association (CSA) and Consumer Electronics Association (CEA) designs	No
Special designs to meet international specifications	No
Load break switches	No
Drain/sampling valve	Yes
Pressure vacuum gauge	Yes
Liquid level gauge1	Yes
Temperature gauge1	Yes
Combination shipping and installation poly-pad	No

Network transformer options and accessories

Option or Accessory	Potential for "Aftermarket Installation"
Series-multiple high-voltage winding	No
Delta-wye connection	No
Special high-voltage taps	No
Special low-loss high efficiency designs	No
Design optimization to lowest total owning cost	No
50 Hertz operating frequency	No
Special impedance	No
Special sound level	No
Special phase relationship	No
Special BIL level	No
Over excitation capability	No
65° C average temperature rise	No
Special ambient temperature	No
Operation at altitudes above 3300 feet	No
Core ground test point located inside tank accessible from bolted handhole	No
Electrostatic shields	No

Network transformer options and accessories (continued)

Option or Accessory	Potential for "Aftermarket Installation"
Optional tank features and accessories	--
Special hardware	No
Welded handhole cover	No
Additional bolted or welded hand-hole	No
Special tank design pressure (up to 15 psig)	No
Ground connectors	Yes
Special tank dimensions	No
Tank undercoating	No
Omit pressure-relief valve	No
Optional gauges and fittings	--
Dial-type magnetic liquid-level gauge (with alarm contacts)	No
Dial-type thermometer (with alarm contacts)	No
Pressure-vacuum gauge (with or without alarm contacts)	No
Automatic pressure-relief device (with or without alarm contacts)	No
Drain valve with liquid sampling valve	Yes
Additional drain valve on tank or switch chamber	Yes
Spare gaskets	Yes
Sight gauge for high-voltage terminal chamber	Yes

Network transformer options and accessories (continued)

Option or Accessory	Potential for "Aftermarket Installation"
Optional high-voltage entrance features and accessories	--
Single-conductor or multi-conductor wiping sleeves, or pothead entrance	No
Six universal bushing wells for loop feed with or without loadbreak inserts	No
Three integral loadbreak bushings	No
Three non-loadbreak bushings	No
Six non-loadbreak bushings for loop feed	No
Optional low-voltage air terminations	--
Welded low-voltage bushings	No
Fully insulated low-voltage neutral bushing	No
Other low-voltage termination options	No
Optional network protector provisions (check with factory)	No
Optional dielectric fluids	--
Silicone fluid	No
FR3 natural ester-based fluid	No

Network transformer options and accessories (continued)

Option or Accessory	Potential for "Aftermarket Installation"
Optional high-voltage switch features and accessories	--
Interrupting switch or other special switches	No
Provisions for phase sequence identification	No
Phase sequence indication	No
Additional electrical interlocks	No
Viewing windows for observation of switch blades	No

Input on kVA Sizing

Input on kVA Sizing

- Action points – Attribute Consolidation
  - Agreement to eliminate 3-15kVA 1ph OH variations – Start evaluation with 25kVA 1 Ph OH
    - Evaluate impacts such as higher losses/lower efficiency, physical size, cost, heat losses
    - Evaluate change in construction specs (pole size, pad size, line crew)
    - Need to develop Cost benefit analysis

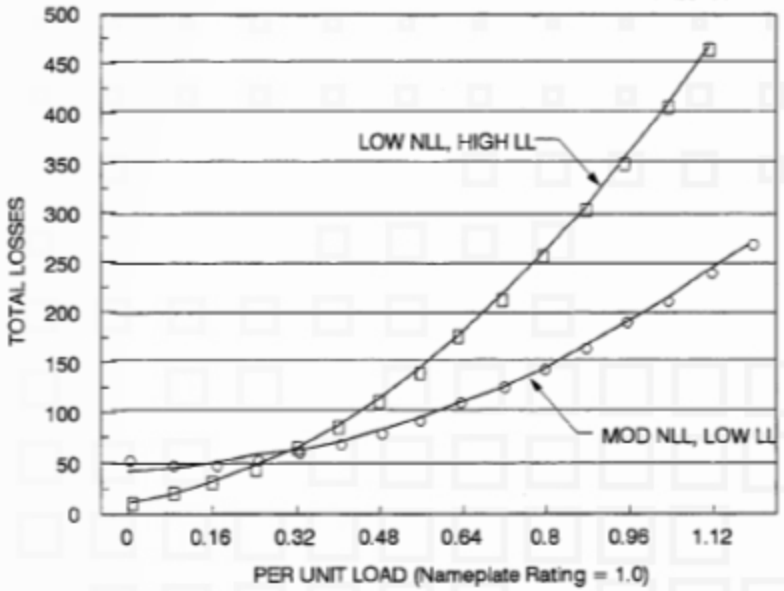
1P pole top	Utility 1	Utility 2	Utility 3	Utility 4
.5 (1440)				
1 (1440)				
1.5 (1440)				
3 (1440)				
5 (1440)				
10 (1440)				
15 (1440)				
25 (1440)				
37.5 (1440)				
50				
75				
100				
167				
250				
333				
500				
750				

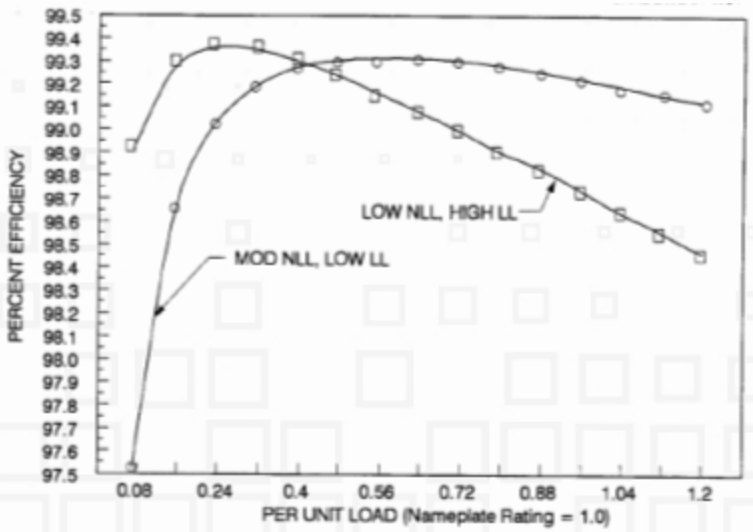
1P Pad	Utility 1	Utility 2	Utility 3	Utility 4
10 (360)				
15 (360)				
25				
37.5				
50				
75				
100				
167				
250				

3P pad	Utility 1	Utility 2	Utility 3	Utility 4
45				
75				
112.5				
150				
225				
250				
300				
500				
750				
1000				
1500				
2000				
2500				
3000				
3750				
5000				
7500				
3750				

Input on kVA Sizing

- Compare impact of moving from a 15kVA to 25kVA to 50kVA 1 Ph OH
  - Evaluate the TOC impact and considerations of this shift
    - Increased Purchase price – with standardization the overall piece price may decrease, but still a higher initial purchase cost
    - NLL (W) – No Load Losses – No load losses will be higher for same type construction
    - LL (W) – Load Losses -- Load Losses will be lower assuming the same load
    - A ($/W) = Capitalized cost of No Load Losses (unique to each purchaser/industry)
    - B ($/W) = Capitalized cost of Load Losses (unique to each purchaser/industry)





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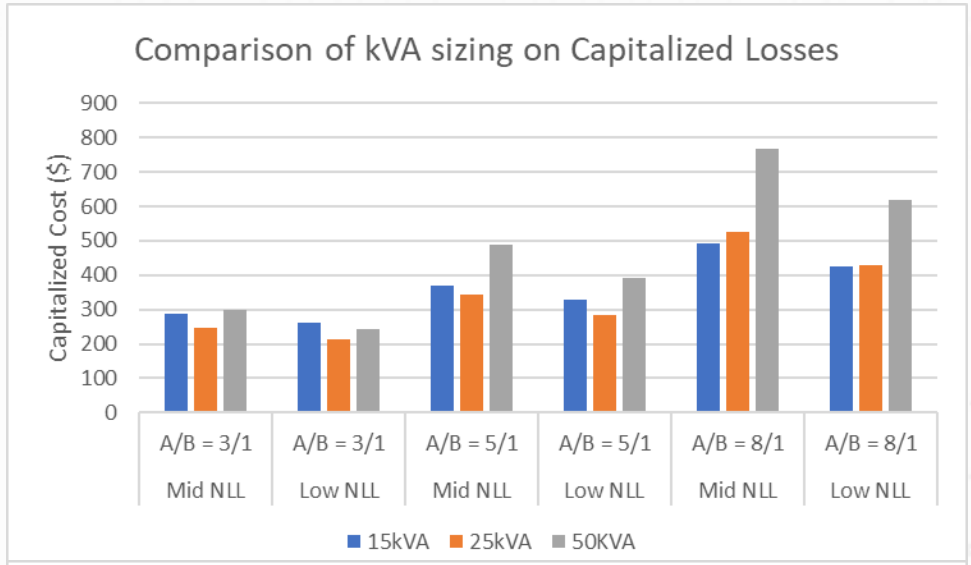
Ways to Reduce No-Load Losses
Better grade/ lower loss core materials
Thinner core steel laminations
Decrease flux density – increasing core CSA
Decrease flux path length – decreasing conductor CSA

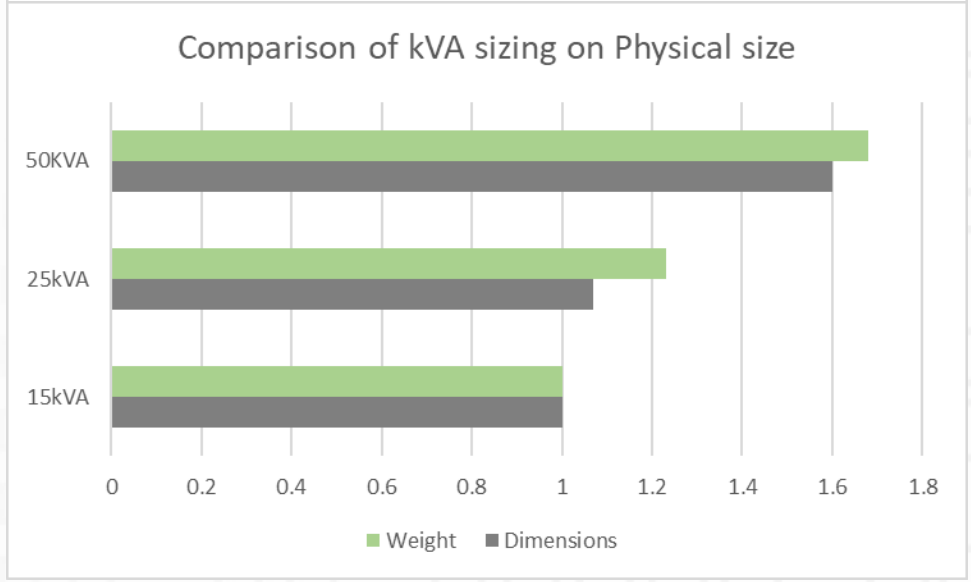
Ways to Reduce Load Losses
Lower loss conductor materials
Decrease current density – increasing conductor CSA
Decrease current path length – increasing volta/turn, decreasing core CSA

Input to the A and B factors
Average energy costs
Number of years for ROI
Transformer loading
Annual inflation rate
Annual increase in energy cost
Annual increase in loading
Transformer life expectancy
Fixed load vs. Variable load

Input on kVA Sizing

- Compare impact of moving from a 15kVA to 25kVA to 50kVA 1 Ph OH
  - Evaluate the TOC impact and considerations of this shift





- Comparison of multiple vendors with range of NLL and LL
- All values represent a composite average
- Low NLL value considered represent 20% reduction from actual
- The same load level was assumed across all sizes
- Size elements were normalized by volume and filled weight to 15kVA sizing

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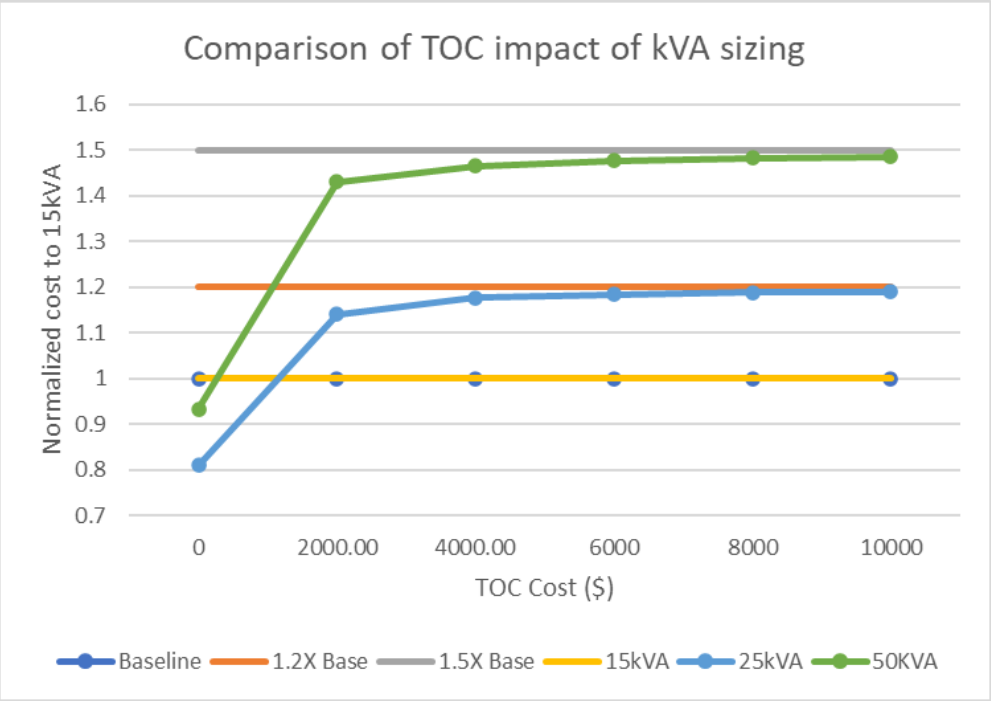
Input on kVA Sizing

- Compare impact of moving from a 15kVA to 25kVA to 50kVA 1 Ph OH
  - Evaluate the TOC impact and considerations of this shift



- Evaluation of TOC cost impact for different purchase points
- All values normalized to 15kVA sizing
- Compared to baseline, 25kVA and 50kVA assumed to have 20% and 50% higher initial cost respectively
- All Loss impacts have an initial reduction on the operating cost (previous assumptions). Depending on load profiles, the loss impact may be further decreased (1-3%)
- The same load level was assumed across all sizes

Input on kVA Sizing

- Compare impact of moving from a 15kVA to 25kVA to 50kVA 1 Ph OH
  - Evaluate the TOC impact and considerations of this shift
    - Increased Purchase price – with standardization the overall piece price may decrease, but still a higher initial purchase cost
    - NLL (W) – No Load Losses – No load losses will be higher for same type construction
    - LL (W) – Load Losses -- Load Losses will be lower assuming the same load
  - Size and weight impacts – need to consider impacts to transportation (cost, logistics, placement)
  - Potential Benefits
    - Reduction of lead times for standardized products
    - Standardized replacement, load calculations, ordering/inventory management
    - Longer duration peak load without lifetime degradation
    - Growth opportunities for future loads without replacement
    - Environmental benefits of lower operating losses

Input on kVA Sizing

- More information is needed to refine the analysis for a larger vendor pool
  - Impact on cost for standardization and economy of scale
  - Additional data can be reviewed quickly in the current format
  - Specific impact factors can be considered for refinement

- What further information would be helpful to evaluate the kVA sizing?
- Potential investigation into 3ph pad mount standardization
  - Similar considerations for standardizing 30kVA, 45kVA and 75kVA to just 75kVA
  - Similar considerations for standardizing 225kVA, 250kVA and 300kVA to just 300kVA

Identify additional Critical Design Specifications – that impact internal design and number of SKUs not already captured

Identify additional Critical Design Specifications – Summary Points

- FR3 Fluid – No gain in efficiency at manufacturer not practical for aftermarket, what does utility do with the replaced oil
- International specifications – may need to be open due to supply chain issues
- CSA/International Standards – Need to look at IEEE vs. CSA, some manufacturers/utilities may need both
- OS SS Tank Hardware -- most rust on cover so consider Lid/Ring as stainless, Mild steel tank
- OH (current limit fuse/MOV) can use separate fusing and arrestor for protection
- Stenciled designations – need some type of permanent label
- Impact to Manufacturers' warranty – for additions or aftermarket install
- SS Tank/sill/hardware – corrosive environment, network underground applications
- Sill Service Entrance – may require change in processes/policies
- Practicality of Aftermarket installation for valves and gauges
- Some connections/terminals and inserts can be done aftermarket – were put to manufacturers when material/labor not issues, value added efficiency and cost impact on manufacturer vs. utility

Goal 3: Interchangeability Matrix for Components

Develop Interchangeability Matrix for Components

- What primary components are currently being substituted to expedite delivery?
- What are acceptable long-term substitutions vs. short-term needs for delivery?
- Categorize vendor requirements to ensure suitable substitution performance and quality

Transformer				Preferred Manufacturer		Alternate Manufacturer		Alternate Manufacturer		Substitution Status		Specific Vendor Requirements			
Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	kVA	Fuse, Sticker, MOV	Protection, Marking							Only to expedite	Completely interchangeble	Critical matching requirements	Test specs or other metrics		Ability to add at Utility

Develop Interchangeability Matrix for Components

Transformer				Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Substitution Status		Specific Vendor Requirements			
Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	kVA	Fuse, Sticker, MOV	Protection, Marking															Only to expedite	Completely interchangeble	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
OH 1 Phase	50kva and smaller	Interlaced windings		Allowing Non-Interlaced Windings															Only one manufacturer has asked for this at this time				No
OH 1 Phase	All kva	Tap Changers									5 Approved Mfgs												No
OH 1 Phase	All kva	Dual Voltage Switches									5 Approved Mfgs												No
1 Phase Pad	All kva	Transformer Tank Bronze Ground Clamps		H-J Enterprises, Inc.		Kearney		Penn Union											Completely interchangeble				No
1 Phase Pad	All kva	Pressure Relief Valves		Qualitrol		Beta		Heartland											Completely interchangeble				No
1 Phase Pad	All kva	Bushing Wells 125kV BIL		Elastimold		ERMCO		ABB		Central Moloney		Cooper							Completely interchangeble				No
1 Phase Pad	All kva	Bushing Wells 150kV BIL		Elastimold		Central Moloney		Howard											Completely interchangeble				No
1 Phase Pad	All kva	Bay-o-net assembly		Cooper		ABB													Completely interchangeble				No
1 Phase Pad	All kva	Boy-o-net fuse holders		Cooper		ABB													Completely interchangeble				No
1 Phase Pad	All kva	Bay-o-net oil drip shields		Central Moloney		Howard		RTE (Cooper)		ABB		ERMCO							Completely interchangeble				No
1 Phase Pad	All kva	Low Voltage/Neutral Bushings		Cooper		Central Moloney		ABB		Howard		H-J Enterprises							Completely interchangeble				Yes
1 Phase Pad	All kva	Fiber Optic Oil Level Indicator (19.9kV units)		Trayer		Heartland													Completely interchangeble				No
1 Phase Pad	All kva	Non-PCB Label		Almetek		LEM													Completely interchangeble				No
1 Phase Pad	All kva	Bay-o-net Fuse		ERMCO		Cooper		ABB											Completely interchangeble				No
1 Phase Pad	All kva	Current Limiting Fuse		Cooper		GE/Mersen		Hi-Tech											Completely interchangeble				No
3 Phase Pad	All kva	Transformer Tank Bronze Ground Clamps		H-J Enterprises, Inc.		Kearney		Penn Union											Completely interchangeble				No
3 Phase Pad	All kva	200A Bushing Wells 12kV, 20kV, 25kV		Central Moloney		Central Moloney		Howard											Completely interchangeble				No
3 Phase Pad	All kva	200A Bushing Wells 35kV		Elastimold															Completely interchangeble				No
3 Phase Pad	All kva	Low Voltage/Neutral Bushings		Cooper		Central Moloney		ABB		Howard		H-J Enterprises		ERMCO		Elastimold			Completely interchangeble				No
3 Phase Pad	All kva	Bay-o-net fuse assembly		RTE/Cooper		ABB													Completely interchangeble				No
3 Phase Pad	All kva	Pressure Relief Valves - Fuse Compartment		Qualitrol		Tomco		Heartland											Completely interchangeble				No
3 Phase Pad	All kva	Pressure Relief Valves - Secondary Compartment		Qualitrol		Viat Instruments													Completely interchangeble				No
3 Phase Pad	All kva	Pressure Relief Valves - Transformer Tank Top		Qualitrol															Completely interchangeble				No
3 Phase Pad	All kva	Fiber Optic Oil Level Indicator		Trayer		Heartland													Completely interchangeble				No
3 Phase Pad	All kva	Tap Changer (5 or 7 position)		Cooper															Completely interchangeble				No
3 Phase Pad	All kva	Non-PCB Label		Almetek		LEM													Completely interchangeble				No
3 Phase Pad	All kva	Under Oil Arrester Ground Lead Disconnet Switch		Cooper															Completely interchangeble				No

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Develop Interchangeability Matrix for Components

Transformer				Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Substitution Status		Specific Vendor Requirements			
Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	kVA	Fuse, Sticker, MOV	Protection, Marking															Only to expedite	Completely interchangeble	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
3 Phase Pad	All kva	Bay-o-net Fuse		Cooper		ABB		ERMCO											Completely interchangeble				No
3 Phase Pad	All kva	Current Limiting Fuse		GE/Mersen		Cooper		Hi-Tech											Completely interchangeble				No
OH 1 Phase		Arrester Bracket Gua	Animal Guard	CENTRAL MOLONEY	70380348																		
OH 1 Phase		Arrester Top Guard	Animal Guard	RELIAGUARD	LA-13002																		
OH 1 Phase		10kV MOV	Lightning Arrester	Cooper	UHS10050AL81B1A	Maclean	ZRP010-0C00163	HUBBELL POWER SYS	213709-6367										Completely interchangeble				
OH 1 Phase		6kV MOV	Lightning Arrester	Cooper	UHS06040A1A1B1A	Maclean	ZHP006-0C00100-0L	HUBBELL POWER SYS	213705-7324	GE	9L23AXX006AC	ABB	PHO6DAD021						Completely interchangeble				
OH 1 Phase		27kV MOV	Lightning Arrester	Cooper	UHS27110A1A1B1A	Maclean	ZHP027-0C00100-0L	HUBBELL POWER SYS	213722-7324	GE	9L20AXX027AH								Completely interchangeble				
OH 1 Phase		Magnex	Protection	Cooper	MX1AE1SYE12														Completely interchangeble				
OH 1 Phase		Magnex	Protection	Cooper	MX1AE1SYE25														Completely interchangeble				
OH 1 Phase		Magnex	Protection	Cooper	MX1AE1SYE30														Completely interchangeble				
OH 1 Phase		Magnex	Protection	Cooper	MX1AE1SYE40														Completely interchangeble				
OH 1 Phase		Shunt Kit F/ Magnex	Protection	Cooper	3638535A05														Completely interchangeble				
OH 1 Phase		Isolation Link	Protection	Cooper	36730803B10														Completely interchangeble				
OH 1 Phase		Isolation Link	Protection	Cooper	36730803B03														Completely interchangeble				
OH 1 Phase		Isolation Link	Protection	Cooper	36730803B05														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE03														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE06														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE10														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE12														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE18														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE25														Completely interchangeble				
1 Phase Pad		Magnex	Protection	Cooper	MX1AE1SYE30														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08030C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08040C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08050C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08065C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08100C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08125C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08150D100														Completely interchangeble				
1 Phase Pad		Sticker	Marking	Almetek	17261														Completely interchangeble				
1 Phase Pad		Sticker	Marking	Almetek	17262														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C04														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C10														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C12														Completely interchangeble				

Develop Interchangeability Matrix for Components

Transformer				Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Substitution Status		Specific Vendor Requirements			
Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	kVA	Fuse, Sticker, MOV	Protection, Marking															Only to expedite	Completely interchangeble	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C14														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C17														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08080C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC08165D100														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C06														Completely interchangeble				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C08														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC23030C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC23050C100														Completely interchangeble				
1 Phase Pad		ELSP	Protection	Cooper	CBUC23080C100														Completely interchangeble				
1 Phase Pad		Magnex Hardware Ki	Protection	Cooper	3638535A08														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV125														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV035														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV014														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0919														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0256														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0108														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0102														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0029														Completely interchangeble				
1 Phase Pad		Magnex Shunt Kit	Protection	Cooper	MXDV0025														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08030C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08040C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08050C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08065C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08080C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08100C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08125C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08150D100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC08165D100														Completely interchangeble				
3 Phase Pad		Sticker	Marking	Almetek	17261														Completely interchangeble				
3 Phase Pad		Sticker	Marking	Almetek	17262														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C04														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C06														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C08														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C10														Completely interchangeble				

Develop Interchangeability Matrix for Components

Transformer				Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Approved Manufacturer		Substitution Status		Specific Vendor Requirements			
Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	kVA	Fuse, Sticker, MOV	Protection, Marking															Only to expedite	Completely interchangeble	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C12														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C14														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C16														Completely interchangeble				
3 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C17														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC23030C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC23040C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC23050C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC23080C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC23100C100														Completely interchangeble				
3 Phase Pad		4-Position Switch	Switch	Cooper	LS4RH3T12M														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC15030C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC15050C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC15080C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC15125C100														Completely interchangeble				
3 Phase Pad		ELSP	Protection	Cooper	CBUC15150D100														Completely interchangeble				

Technical challenges of manufacturers

- Renewable growth is causing unexpectedly high harmonics, cyclical loading profiles, and additional stresses on transformers
- For transformer interoperability and standardization, the internal configuration of the transformers may need to be addressed first to provide a base function model, which may drive the growth of external bolt-on alternatives
- Concern if the current supply chain constraints dissipate in the next few years, the utility sector may resort back to requiring its preferred suppliers and level of customization. This could lead to an unwanted inventory of standard models or factories focused on building standard designs

Technical challenges of manufacturers

- Standardization options must also consider that all manufacturers have different methods, shop configurations, and manufacturing techniques, so the standard base model concept may need to have some flexible boundary conditions
- A concern with the concept of increased standardization and interoperability for manufacturers relates to tooling, timing, and staffing for these designs to increase production capability for the current market

Proposed next steps

- Manufacturers feedback on the Standardization information collected from utilities
  - What additions would be helpful?
  - What differences are seen from the Manufacturers experiences?
- Manufacturers to provide feedback and priority on DOE identified challenges and any others they see
- Review of technical challenges of Manufacturers
- Next meeting will be November 29

Manufacturer Feedback on Utility Content

Manufacturer Feedback on Utility Content

- Standardization impacts:
  - Reduce number of SKUs so potential improvement on setup times, minimize stocking requirements, minimize tooling sets needed
  - Standardization in kVA may help, but needs to be accompanied by a Standardized accessory/components package
  - Create efficiency in winding – Reduce winding time, Winding units are limiting or takt setting factor, potential for reduced inventory on conductor types
  - Potential to reduce process errors and product variations with longer/consistent lot runs
  - Ability to use inventory on hand for emergency needs (mutual assistance)
  - Impact on levels of automation due to the variation in types and numbers of accessories
- Review impact of 1 voltage vs. Multiple taps and duals
  - Impact on Pole vs. Pad mount
  - Tradeoff of manufacturing complexity and time compared to reduced SKUs
  - Number of high side voltages
  - Potential for standardized impedance for range of kVA sizes
- Interchangeability Matrix
  - Need support through utility specifications
  - Long term commitments rather than just to support product expediting/availability
  - Impact of operational differences to design/acceptance/implementation across regions and utilities groups
  - Understanding to the current number of component suppliers and variations and agreement on what is deemed acceptable

Manufacturer Feedback on Utility Content

- Single source components
  - Options for dual sourcing
  - Alternate technology replacement
  - New component research needed
- Need demand vs. capacity outlook
  - Investments in capacity and CAPEX
  - Forecasting/availability for critical materials
  - Forecasting/availability for components
- Impact of Electrification and Changing Grid needs on Capacity and Sizing
  - Make sure these items are included in the reasoning for down selection and planning
- Impact of Renewables – higher temperature insulation (solid/liquid) and need for shielding
  - Can this be leveraged to supply wider range of standard products rather than individual custom solutions?
  - Impact of cost and lifetime for the different systems
- Negative considerations of standardization
  - Increased material usage if not utilizing the full kVA capacity
  - Time for redesign to accommodate new standardized approach
  - Can current tooling/processes handle higher volume of consolidated kVA sizes

Manufacturer Feedback on Utility Content

- Similar input on kVA Sizing
  - 1ph Pole top higher volume 25kVA or 50kVA rather than 5-15kVA or 37.5kVA respectively
  - 3ph Pad mount
    - Similar considerations for standardizing 30kVA, 45kVA and 75kVA to just 75kVA
    - Similar considerations for standardizing 225kVA, 250kVA and 300kVA to just 300kVA

	Manufacturing Volume	Variations or SKU numbers	Manufacturing Volume	Variations or SKU numbers
	MFG 1	MFG 1	MFG 2	MFG 2
1P pole top				
.5 (1440)				
1 (1440)				
1.5 (1440)				
3 (1440)				
5 (1440)				
10 (1440)				
15 (1440)				
25 (1440)				
37.5 (1440)				
50				
75				
100				
167				
250				
333				
500				
750				

	Manufacturing Volume	Variations or SKU numbers	Manufacturing Volume	Variations or SKU numbers
	MFG 1	MFG 1	MFG 2	MFG 2
3P pad				
45				
75				
112.5				
150				
225				
250				
300				
500				
750				
1000				
1500				
2000				
2500				
3000				
3750				
5000				
7500				
3750				

Input of Interest		
Manufacturing Volume	High	
	Medium	
	Low	
	N/A	
Variations or SKU numbers	High	
	Medium	
	Low	
	N/A	

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Benefits and impacts of the short-term goals

Discussion topics for consideration leading into Combined meeting

- Consideration of Single voltage vs. Dual/Multiple Taps
  - Impact to manufacturing time, component availability, number of connections, and total line throughput
    - Basic quantification of potential increase in production efficiency
    - Impact to critical supply chain areas, lead times, and cost
  - Impact to utilities for planning and inventory
    - For a given classification (kVA range, region, etc.), how many voltages need to be supported and what is the distribution?
- Standardized Transformer considerations
  - Basic production/process flow and allocation of relative time per step
    - What components of standardization can make the most impact?
  - Balance of kVA sizing and standard accessory packages
    - With commitment to this as long-term effort, what is impact to ability to increase production volume, reduce production time, ability to automate, reduce amount of material variations and component inventory, etc.?
  - Negative impacts for consideration
    - Increased materials usage to support larger kVA standardization as capability may not be fully utilized in the short term
    - Design time to accommodate the new standard configuration as compared to current operating designs
    - Some current hard tooling and machinery may have constraints for increased volume or upsizing
  - Anatomy of functional vs. IEEE standard vs. specialized
    - Minimum functional components needed vs. expected vs. wanted?
    - What are the minimum number of specialized components needed?
  - Labeling and Decal design and placement – standardization, aftermarket application

Discussion topics for consideration leading into Combined meeting

- Develop demand vs. capacity forecast
  - Impact of current requirements and expectations
  - Impact of changing grid due to electrification and renewables on what sizes and quantity expected
  - Repair and replacement – expected to be 1:1 or sized for increased electrification
  - What happens to the standardization efforts in the case of reduced demand?
- Interchangeability Matrix
  - Understanding the number of component suppliers and agreement on acceptable criteria
  - What level of information needed in this matrix i.e. Category and Major Manufacturer as compared to exact part number?
  - What will be the impact of operational differences to design/acceptance/implementation across regions and utilities groups?

Working Documents from Meeting 9
January 10, 2024

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Agenda

Meeting Time: 90 minutes		
DOE	10 minutes	Welcome and introductions
All	25 minutes	Fuse curve update
All	50 minutes	Discussion Topics from December Meeting
DOE	5 minutes	Next steps

Fuse curve update

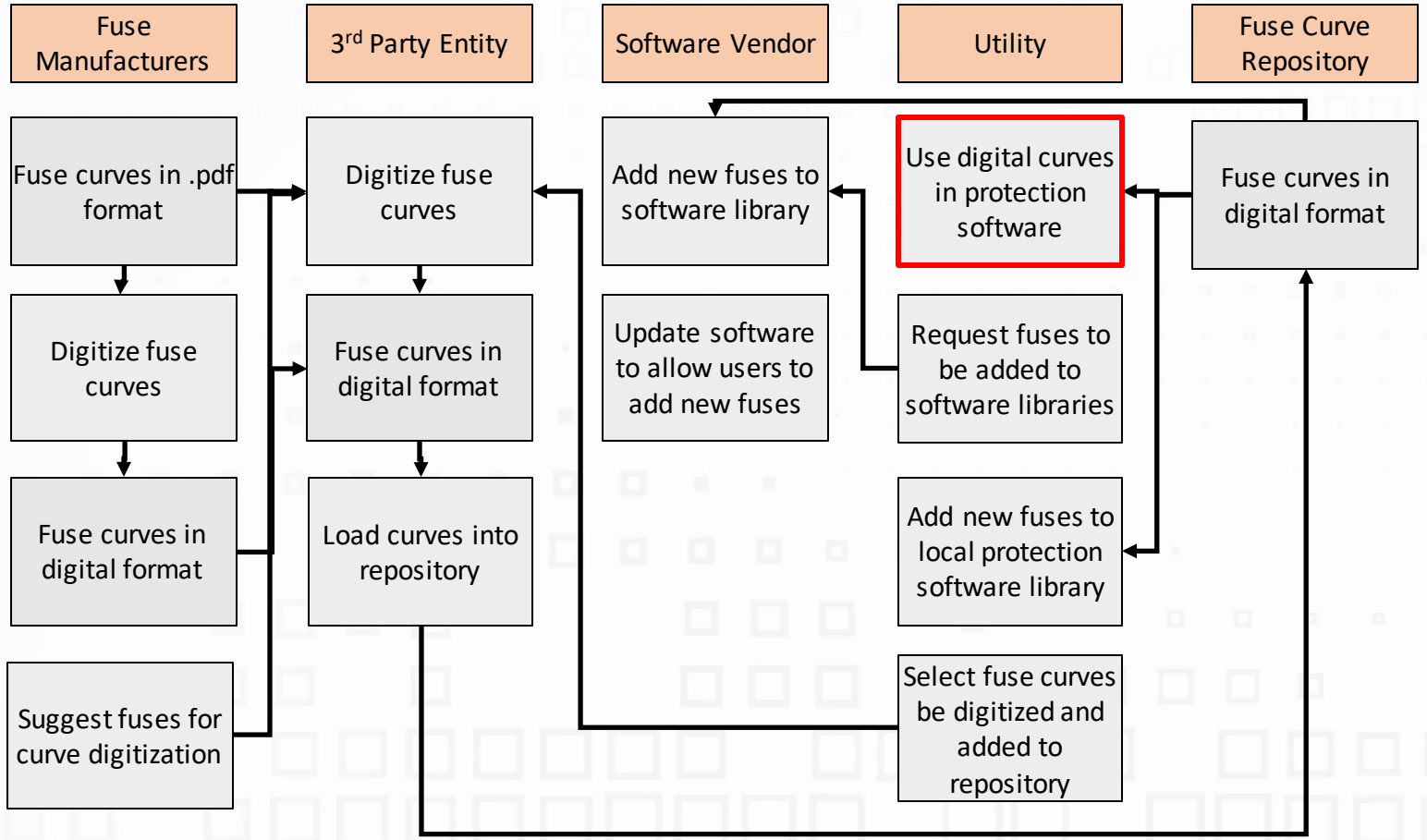
Objective and Context

- Establish a centralized repository of transformer fuse curves to facilitate confirming the compatibility between fuses.
- Such a repository would make it easier for utilities to use protection coordination software confirm that a replacement fuse will provide the same functionality as the original fuse.
- Utilities have reported miscoordination on their systems after replacing a fuse with a supposed "like and kind" replacement.

Fuse Curve Analysis – Stakeholders and Survey Status

Stakeholder	Process Overview
Fuse Manufacturers	Sixteen of the eighteen manufacturers surveyed supply fuse curves only in .pdf format. Two supply fuse curves in either tabular or digital format.
Protection Coordination Software Vendors	Software vendors produce protection coordination software used by utilities and others. Eight of the eleven vendor packages reviewed allow users to add new fuses to the software component library, via tabular or digital (.csv) format.
Utilities	Some utilities perform coordination studies to evaluate fuse interchangeability while others rely on manufacturer guidance to select alternative fuses.

Fuse Curve Repository Process Details (Draft)



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Only two manufacturers surveyed have digital or tabular fuse TCC curves available

Manufacturer	Have digital or tabular files?
ABB	No
Bussman - Eaton	No
Cooper Power - Eaton	No
Cutler-Hammer - Eaton	No
Fuji	No
H-J	No
Kearney - Eaton	No
Littlefuse	No
Mersen	No
Hitachi Energy	No
S&C Electric Company	Yes
G&W Electric	No
General Electric (GE)	No
Hubbell Power Systems	No
Powell Industries	No
Schneider Electric	No
Siemens	No
ERMCO	Yes

Eight software packages allow user input of TCC curves.

Software Vendor	Application	Allow User Input?
Eaton	CYME	Yes
ETAP	ETAP	Yes
Milsoft	Windmill	No (1)
S&C	Coordinade	Yes
SKM	SKM Power Tools	No (1)
Siemens	PSS Sincal	Unknown (2)
Elite Software	E-Coord	Yes
Easypower	Easypower P&C Module	Yes
Aspen	OneLiner	Yes
Siemens	PSS-Cape	Yes
DigSilent	Power Factory - Prot. Module	Yes

(1) Manufacturer will update software with curves as requested
(2) Siemens refused to provide information

Discussion Topics from December Meeting

Discussion topics for consideration leading into January meeting

- Consideration of Single voltage vs. Dual/Multiple Taps
  - Impact to manufacturing time, component availability, number of connections, and total line throughput
    - Basic quantification of potential increase in production efficiency
    - Impact to critical supply chain areas, lead times, and cost
  - Impact to utilities for planning and inventory
    - For a given classification (kVA range, region, etc.), how many voltages need to be supported and what is the distribution?
- Standardized Transformer considerations
  - Basic production/process flow and allocation of relative time per step
    - What components of standardization can make the most impact?
  - Balance of kVA sizing and standard accessory packages
    - With commitment to this as long-term effort, what is impact to ability to increase production volume, reduce production time, ability to automate, reduce amount of material variations and component inventory, etc.?
  - Negative impacts for consideration
    - Increased materials usage to support larger kVA standardization as capability may not be fully utilized in the short term
    - Design time to accommodate the new standard configuration as compared to current operating designs
    - Some current hard tooling and machinery may have constraints for increased volume or upsizing
  - Anatomy of functional vs. IEEE standard vs. specialized
    - Minimum functional components needed vs. expected vs. wanted?
    - What are the minimum number of specialized components needed?
  - Labeling and Decal design and placement – standardization, aftermarket application

Discussion topics for consideration leading into January meeting

- Develop demand vs. capacity forecast
  - Impact of current requirements and expectations
  - Impact of changing grid due to electrification and renewables on what sizes and quantity expected
  - Repair and replacement – expected to be 1:1 or sized for increased electrification
  - What happens to the standardization efforts in the case of reduced demand?
- Interchangeability Matrix
  - Understanding the number of component suppliers and agreement on acceptable criteria
  - What level of information needed in this matrix i.e. Category and Major Manufacturer as compared to exact part number?
  - What will be the impact of operational differences to design/acceptance/implementation across regions and utilities groups?

Discussion topics

- What changes can be considered?
  - Single vs. Multiple Voltages
  - Streamlining kVA Sizing combined with Standard Accessory package
- What technical solution items would provide the most help for higher production throughput and lower lead times?
  - How to quantify or normalize between manufacturers, technology type, region, etc.?
  - Options to address current backlog in addition to future orders
- Outline of the production timeline/lead time for IEEE standard transformer compared to different levels of custom specification
- Different component groups which could be accepted/included in the Interchangeability Matrix
- Input on demand vs. capacity forecast

Discussion topics

- Impact to Manufacturing Lead Time based on Features
  - Not a detailed list just some starting examples

Minimalist	Standard Accessories	Regional Standard Accessories	Utility Specific Requests	Added Accessories or Features
Standard Tank materials and Coating Single AWR No switches or tap changers (Tap changers, 4 position switch, dual voltage switch) Labels (decals) No overcurrent protection OVP Normal duty surge arrestor Simplest/Common core design No additional Accessories Bushings -- standard	Standard Tank materials and Coating Single AWR Tap changers OVP Normal duty surge arrestor OCP – Fuse protected Bushings- specific size/location	SS Tanks, cover, hardware	Specific core/AWR design 4 position Switch CSP Custom label/markings/decals Arrestors under oil Magnex Breakers Internal/external Secondary OVP	Bird Guards 15kV insulated cover IFD Vacuum pressure gauge Fluid level gauge Temperature gauge Drain valve with sampling

Working Documents from Meeting 10
January 31, 2024

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Agenda

Meeting Time: 90 minutes		
DOE	5 minutes	Welcome and introductions
All	20 minutes	Discussion of Critical Components
All	60 minutes	Discussion of Configuration Matrix
DOE	5 minutes	Next steps

Discussion of Critical Components

Identification of Critical Components and Accessories

- Identify components and accessories that might impact lead times and deliveries
- Develop a list for further investigation to support reduction in lead times and standardization

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments
Protection -- Bayonet Fuses	RTE/EATON COOPER BAY-O-NET FUSES DUAL SENSING W/DRIP SHIELDS & OIL RETAINING VALVES & ISOLATION LINKS	15		5	Components used are sourced from overseas by supplier. Some are Sole Sourced (Hi-Amp family)
Protection -- Current Limiting	35kV transformers, Three RTE oil Bay-O-Net with load sensing fuses in series with back up ELSP current limiting fuses	9		6	Critical component for transformers that utilize internal protection for high fault current applications. Component parts sourced from overseas by supplier. Fuses with similar ratings across manufacturers are not necessarily interchangeable, have to be individually coordinated against transformer and smaller fuse selection. Highly specified component from end users.
Bayonet Assembly or Fuse Holders	Cooper Bay-O-Net fuses, DS indicates Dual Sensing Bay-O-Net fuse, HA indicates High Ampere Overload Bay-O-Net fuse	16		7	Critical component for padmount transformers that utilize internal protection. Production constraints.
Protection -- Isolation links	PER ABOVE LI#1	17		10	Critical component for padmount transformers that utilize bayonet fusing. Production constraints
Protection -- Magnex Breakers & LV Breakers	N/A	3	Single Source and long lead times	12	Single Source
Protection -- Fuse Cartridge	PER ABOVE LI#1	11		8	
Primary Arresters -- Normal Duty/Heavy Duty	N/A Separate Accessory Installed by Utility	1	LT over 1 year on special purpose models that are from single source	4	Extremely high market demand across manufacturers over last few years with growth in overhead demand. High number of SKU's for various configurations.
Primary Arresters -- Under Oil	N/A	5		11	Optional accessory, application can be achieved through other means.
Secondary Arrester -- Internal/External MOV	N/A	8		17	Optional accessory that can be installed in field.
Tap Changers (5 position, 7 Position)	N/A	6		9	Critical component for transformers that includes adjustable taps. 7-position tap changers sole sourced and considered non-standard. 5-position considered default tap changer. Contact shortages at supplier.
Dual Voltage Switches	N/A	7		2	Critical component for dual voltage designs. Contact shortages at supplier.
4 Position Switches	N/A	2	Single Source and long lead times	1	Sole source. Contact shortages at supplier. Optional accessory, application can be achieved through other means.

Identification of Critical Components and Accessories

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments
LBOR Switches	35 kV Cooper Power Catalog Number 2200912C21M or equivalent	4	Typically with long lead times	3	Critical component for transformers that include internal load break switching. Contact shortages at supplier.
High Voltage Bushings	35kV Small Elastimold Interface	10		14	
Low Voltage Neutral Bushings	Secondary bushings with threaded studs and screw on terminals are NOT acceptable. All secondary bushings with 8 holes or greater must be equipped with external supports.	12		15	
Bushing Wells	35kV Small Elastimold Interface	13		19	
15kV Insulated covers	N/A Separate Accessory Installed by Utility	14		29	
Stainless Steel Tank/Hardware	Stainless steel hinges and stainless steel pins (type 304) shall be provided	19		27	
Internal Fault Detector	Single Source	18		13	Single Source
Pressure Relief Valves	Yes	21		25	
Oil Level Indicators	Yes	27		23	Optional accessory
Dielectric Fluids -- Mineral Oil or Esters	Non-PCB Mineral Oil	29		22	
Solid Insulation	N/A	20		21	
Grounding Clamps	HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ ENTERPRISES AS1409-005.	23		16	Optional accessory that can be installed in field.
Animal guards	N/A Separate Accessory Installed by Utility	28		20	Optional accessory that can be installed in field.
Creep Bushings	N/A	22		18	
Vacuum Pressure Gauge	Larger kVA's	26		28	Optional accessory
Drain valve with sampling	Yes	24		26	
Temperature Gauge	Yes	25		24	Optional accessory

Discussion of Configuration Matrix

Configuration Matrix

- Outline target configurations ranging from minimum requirements to full customization from both the Manufacturer and Utility perspectives
- Impact to Manufacturing Lead Time based on Features

Minimal configuration to support transforming power safely.	Baseline configuration which includes minimal number of standard components to provide IEEE standard requirements and	Common custom specification to accommodate specific utility requests for configuration, component locations, and	Configuration to accommodate specific regional accessories or materials required. This should be similar to the Standard	These added Accessories or Features would be considered selected options that may intermittently impact the standard or custom
General Comments:	General Comments:	General Comments:	General Comments:	General Comments:
Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration	Regional Standard Accessories Configuration	Added Accessories or Features
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead

Input for 1 Phase OH Configurations

Minimalist Configuration				
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead
No taps	Mild Steel Tank with IEEE C57.12.28 Coating System	65C Rise	Primary Bushing Rated for System Voltage	Creep Bushings
Non-Dual Voltage Primary	Sealed tank construction with bolted on cover	Minimum BIL ratings	Type II mineral insulating oil per ASTM D3487	Pressure Relief Valves
No Fuses	No taps in HV winding	1 - HV cover mounted bushing w/ clamp type terminals	Standard support lugs and lifting lugs	Oil Level Indicators
No Breakers	Single Cooling rating 65°C AWR	3 - secondary side mounted bushings w/ clamp type terminals (except 167kVA)	Removable tank cover with minimum dielectric strength of 8kV	Dielectric Fluids -- Mineral Oil or Esters
No Arrester	DOE 2016 Minimum Efficiency Compliant	Low voltage neutral copper ground strap from X2 to tank.	Nitrile rubber seal type gaskets	Grounding Clamps
No gauges	No Switches on LV or HV	Tank grounding connector (accepts #8 to #2 AWG conductor)		Low Voltage Neutral Bushings
Enclosure material - mild steel	LV winding suitable for Series-Multiple connections (120/240 V or 240/480 V)	IEEE mounting brackets		
Markings - none	Standard Impedance as per DOE	Lifting lugs/hanger brackets		
Fluid - mineral oil	1 or 2 bushings in HV, 3 or 4 bushings in LV, livefront type	IEEE PRV		
Single Hanger Mounting	Full Capacity Windings HV and LV	Nameplate		
	No fusing or Secondary breaker protection			

Standard Baseline Configuration				
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead
No taps	Dual Voltage switch standard 2:1 ratio	Weak Link primary protection	Pressure relief valve	Primary Arresters -- Normal Duty/Heavy Duty
Non-Dual Voltage Primary	ANSI Gray No. 70 Color	ANSI #24 (dark gray) or ANSI #70 (light gray) paint. Coating system to meet IEEE	Mineral Oil	
Conventional or CSP	Standard pressure-relief system (PRV)	%Z per IEEE	Non-Interlaced Windings	
No gauges	Standard decals/stencils for kVA Rating on Tank	65C Rise	Core form or Shell form types	
Enclosure material - mild steel	Standard Nameplate on support lug	Minimum IEEE BIL ratings	Single Voltage	
Markings - none	Single Set of support lugs	1 - HV cover mounted bushing w/ clamp type terminals		
Fluid - mineral oil	Lifting means	3 - secondary side mounted bushings w/ clamp type terminals (except 167kVA)		
Single or Double Hanger Mounting	Minimum Impedance as per IEEE Stds.	Low voltage neutral copper ground strap from X2 to tank.		
	Ground connector in tank	Tank grounding connector (accepts #8 to #2 AWG conductor)		
	LV ground connector and/or connection	IEEE mounting brackets		
	Altitudes of 1000 m (3300 ft) or less	Lifting lugs/hanger brackets		
	Optional Taps in HV winding, 2 above and 2 below, of 2.5%	IEEE PRV		
	Interlaced LV windings	Nameplate		
	DE-energized tap changer with external operation			
	Lightning arrester mounting provision			
	Cover grounding connection			
	Compliance with BIL and Dielectric Test Requirements			

Input for 1 Phase OH Configurations

Custom Utility Specific Configuration				
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead
Taps	Two sets of support lugs (RUS spec.)	Secondary circuit breaker protection with indictor light (CSP transformer)	2 Primary Bushings Rated for System Voltage	Animal guards
Dual Voltage	Stainless Steel Tank and/or covers (Grades 304 or 409)	Tap changer ((2) +/- 2.5% taps)	Interlaced windings on shell type (50kVA and smaller)	Primary Arresters -- Under Oil
Current Limiting Fuse	Lightning arresters & mounting bracket	Insulated cover	Non-Interlaced windings on core type (75kva and larger)	Protection -- Magnex Breakers
Impedance requirements	Wild life protectors on HV bushings and arresters	Provisions for mounting arresters to tank	Blue 2" x 2" label to indicate less than 2ppm PCB's	Secondary Arrester -- Internal/External MOV
Primary Bushing Creep Distance	Dual Voltage switch standard 3:1 ratio	Labeling unt with Company Stock number	Single Voltage, Dual/Multiple Taps	15kV Insulated covers
Fluid Options	Special Taps in HV winding, as per IEEE Stds. Table	Manufacturered after 1979 sticker		Dual Voltage Switches
Secondary terminations	Single HV Bushing located in middle of cover (RUS spec.)	95kV BIL for 15kV, 150kV BIL for 35kV units		4 Position Switches
Pressure Relief Devices	Special BIL requirements in HV	Weak Link primary protection		Solid Insulation
Markings		ANSI #24 (dark gray) or ANSI #70 (light gray) paint. Coating system to meet IEEE		Stainless Steel Tank/Hardware

Input for 1 Phase OH Configurations

Custom Utility Specific Configuration				
Coastal/Stainless tank and hardware		%Z per IEEE		Internal Fault Detector
Lightning Mitigation Design Considerations		65C Rise		
Ground connectors		1 - HV cover mounted bushing w/ clamp type terminals		Vacuum Pressure Gauge
Shipping Requirements		3 - secondary side mounted bushings w/ clamp type terminals (except 167kVA)		Drain valve with sampling
Fluid		Low voltage neutral copper ground strap from X2 to tank.		Temperature Gauge
Under Oil Arresters		Tank grounding connector (accepts #8 to #2 AWG conductor)		
		IEEE mounting brackets		Protection -- Isolation links
		Lifting lugs/hanger brackets		
		IEEE PRV		
		Nameplate		

Input for 1 Phase OH Configurations

Regional Standard Accessories Configuration				
1 Phase Overhead	1 Phase Overhead		1 Phase Overhead	
Coastal/Stainless tank and hardware	Under oil arresters in HV		Stainless steel tank, cover, & accessories	
Lightning Mitigation Design Considerations	Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)		Extra creep primary bushings	
Primary Bushing Creep Distance	Special AWR ratings (55°C)			
	Expulsion fuse in HV			
	15 kV dielectric strength of cover			
	Special Colors (Desert Tan)			

Added Accessories or Features				
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	
Branding requirements	CSP units with LV Breaker	Lightning arrester provided for CSP transformers	Wildlife protection	
Ground connectors	HV breaker (Magnex)	Animal guards for arrester and arrester bracket	Option for Envirotemp FR3 fluid or equivalent	
Markings	Special application Lightning arresters		Internal Fault Detector	
External protection (arresters/fuses)	Custom fuses in terminal board in HV			
	Dual Voltage switch with odd ratios (fractional)			
	Special AWR (75°C), with high temperature insulating liquids (natural ester)			
	Tap changers with more than 5 tap positions			
	Special taps with more than 10% voltage range			
	Internal Fault Detector			

Input for 1 Phase Pad Configurations

Minimalist Configuration					
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount		1 Phase Pad Mount	1 Phase Pad Mount
No taps	Mild Steel Tank with IEEE C57.12.28 Coating System	65C Rise		Protection -- Bayonet Fuses	HV Bushing wells
Non-Dual Voltage Primary	Sealed tank construction with welded cover	Minimum BIL ratings		Bayonet Assembly or Fuse Holders	HV Loop Feed
Bayonet Fusing with Isolation Link	Tank and compartment with doors to prevent access to terminals and connections	Universal HV bushing well			LV studs
No Breakers	No taps in HV winding	parking stand		Pressure Relief Valves	Drain plug
No Arrester	Single Cooling rating 65°C AWR	3 - secondary bushings supplied with copper studs per IEEE (5/8" for 25-75kVA, 1" for 100 to 167kVA)		Oil Level Indicators	Pressure relief valve
Primary feed - loop	DOE 2016 Minimum Efficiency Compliant	Low voltage neutral copper ground strap from X2 to tank.		Dielectric Fluids -- Mineral Oil or Esters	
Primary bushing arrangement - standard per IEEE - TYPE 2 A	No Switches on LV or HV	(2) Tank grounding connector (accepts #8 to #2 AWG conductor)		Grounding Clamps	
Seconary bushing arrangement - standard per IEEE - TYPE 2 A	LV Windings connected in 240/120 V or 480/240 V three wire configuration	Lifting lugs			
No sectionalizing switches	Standard Impedance as per DOE	IEEE PRV			
Oil fill provision - standard per IEEE	2 deadfront bushings in HV, 3 livefront stud-type bushings in LV	Nameplate			
Oil drain provision - standard per IEEE	Full Capacity Windings HV and LV				
No gauges	No fusing or Secondary breaker protection				
Enclosure material - mild steel					
Markings - none					
Fluid - mineral oil					

Standard Baseline Configuration					
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	
No taps	Pad-mount green color	Loop fed (2 primary bushings)	Pressure relief valve	High Voltage Bushings	
Non-Dual Voltage Primary	Standard pressure-relief system (PRV)	Protection (Bay-o-nets/ELSP)	Mineral Oil	Protection -- Fuse Cartridge	
Bayonet Fusing with Isolation Link	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	Coating system to meet IEEE, Green color			
No Breakers	Standard decals/stencils for kVA Rating on Tank	Doors secured with bolt and provision for a padlock			
No Arrester	Standard Nameplate inside compartment	%Z per IEEE			
Primary feed - loop	Lifting provisions	65C Rise			
Primary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	Minimum Impedance as per IEEE Stds.	Minimum IEEE BIL ratings			
Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	Ground connector in tank	parking stand			
No sectionalizing switches	LV ground connector and/or connection	3 - secondary bushings supplied with copper studs per IEEE (5/8" for 25-75kVA, 1" for 100 to 167kVA)			
Oil fill provision - standard per IEEE	Altitudes of 1000 m (3300 ft) or less	Low voltage neutral copper ground strap from X2 to tank.			
Oil drain provision - standard per IEEE	Tank construction to secure installation on concrete pad	(2) Tank grounding connector (accepts #8 to #2 AWG conductor)			
No gauges	Radial or Loop feed terminal arrangement	Lifting lugs			
Enclosure material - mild steel	Interlaced LV windings	IEEE PRV			
Markings - none	Components for loop primary cable systems (IEEE Std 386)	Nameplate			
Fluid - mineral oil	Parking stands in HV compartment				
No inserts	Lightning arrester attachment				
	Compliance with BIL and Dielectric Test Requirements				

Input for 1 Phase Pad Configurations

Custom Utility Specific Configuration					
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount
Taps	Basic fusing (expulsion fuse in Bayonet with isolation link)	Magnex protection with ELSP current limiting fuses	19.9kV Under Oil Arresters		HV Bushing wells
Dual Voltage	Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	Tap changer ((2) +/- 2.5% taps)	Dual Voltage Switch (when requested)		HV Loop Feed
Specific Bushing Layout	HV fusing with general purpose partial range current limiting fuse, internally mounted	Labeling unt with Company Stock number	19.9kV Under Oil Load Break Loop Switch between H1A and H1B	Protection -- Magnex Breakers	LV studs
Footprint Requirements	Plastic Drip shield for Bayonet	Munsel Green # 7.0 GY3.29/1.5	Optical Liquid Level Gauge (if Load Break Loop Switch present)	Secondary Arrester -- Internal/External MOV	Drain plug
Loadbreak ON/OFF switch	HV Bushing inserts	Maximum dimension of pad to be 37.5" x 43" to fit on standard fiberglass box pad.		Tap Changers (5 position, 7 Position)	Pressure relief valve
Sectionalizing loadbreak switches	LV in Line Terminals mounted on LV bushing studs	Minimum size must fit over a 24" x 26" opening, fully covering opening.		Dual Voltage Switches	HV bushing inserts
Secondary terminations	2 position HV Loadbreak switch	provisions for a 9/16" dia padlock. Hex bolts for securing bolts		4 Position Switches	LV terminations (spades or other)
Gauges	Dual Voltage switch standard 2:1 or 3:1 ratios	Manufacturered after 1979 sticker		Solid Insulation	Decals
Fluid options	Provision for fault indicator	5/16" hole on right side of door for Company tag		Stainless Steel Tank/Hardware	Ground Clamps

Input for 1 Phase Pad Configurations

Custom Utility Specific Configuration					
Markings	Special spacing and locations of components on front tank wall	Clearance and Warning stickers per Company design		Internal Fault Detector	Bayonet fuse with iso link
Impedance requirements	Special BIL requirements in HV	95kV BIL for 15kV, 150kV BIL for 35kV units			
Pressure Relief Devices	Lightning arrester attachment	Loop fed (2 primary bushings)		Vacuum Pressure Gauge	
Coastal/Stainless tank and hardware		%Z per IEEE		Drain valve with sampling	
Ground connectors		65C Rise		Temperature Gauge	
Shipping Requirements				LBOR Switches	
Fluid		parking stand		Protection -- Isolation links	
Internal fusing		3 - secondary bushings supplied with copper studs per IEEE (5/8" for 25-75kVA, 1" for 100 to 167kVA)			
Under Oil Arresters		Low voltage neutral copper ground strap from X2 to tank.			
Primary terminations		(2) Tank grounding connector (accepts #8 to #2 AWG conductor)			
		Lifting lugs			
		IEEE PRV			
		Nameplate			

Input for 1 Phase Pad Configurations

Regional Standard Accessories Configuration					
1 Phase Pad Mount	1 Phase Pad Mount				1 Phase Pad Mount
Coastal/Stainless tank and hardware	Under oil arresters in HV				Stainless Steel Sill and Skirt
	Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)				All Stainless Steel Construction
	HV fusing with general purpose partial range current limiting fuse, internally mounted				
	Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)				
	Special AWR ratings (55°C)				
	Special colors (Gray ANSI 70, Desert Tan)				
	Custom LV in Line Terminals mounted on LV bushing studs with insulation sleeves				

Added Accessories or Features					
1 Phase Pad Mount	1 Phase Pad Mount		1 Phase Pad Mount		1 Phase Pad Mount
Branding requirements	Special fusing with full range current limiting fuse with cannister fuse holder		Primary Bushing Inserts		Bayonet fuseing with partial range current limiting fuses
Ground connectors	HV fusing with utility specific partial range current limiting fuse, internally mounted		Z-Bars		(3) 2-position switches for sectionalizing
Markings	Dual Voltage switch with odd ratios (fractional)		Warning/Notice Label		4-position switch
External protection (arresters/fuses)	Custom fuses in terminal board in HV		Danger Label		Lightning arresters
Primary terminations	4 position HV Loadbreak switch		Option for Envirotemp FR3 fluid or equivalent		Load break Feed-thru inserts
Secondary terminations	Special AWR (75°C), with high temperature insulating liquids (natural ester)				Deeper Cabinet
	Tap changers with more than 5 tap positions				Thermometer
	Special taps with more than 10% voltage range				Liquid Level Gauge
	Internal Fault Detector				DeEnergized Tap Changer
					Less-flammable Natural Ester Fluid

Input for 3 Phase Pad Configurations

Minimalist Configuration				
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Single voltage primary (no Dual Voltage)	Mild Steel Tank with IEEE C57.12.28 Coating System	65C Rise	Protection -- Bayonet Fuses	HV Bushing wells
Standard neutral configuration per IEEE	Sealed tank construction with welded cover and bolted handhole	Minimum BIL ratings	Bayonet Assembly or Fuse Holders	HV Loop Feed
No taps	Tank and compartment with doors to prevent access to terminals and connections	3 - universal HV bushing wells		LV studs
Primary feed - radial	No taps in HV winding	Parking Stands	Pressure Relief Valves	Drain valve and sampler
Primary termination - 35 kV, 200 amp bushing wells	Single Cooling rating 65°C AWR	4 - secondary bushings, NEMA pads per IEEE	Oil Level Indicators	Pressure relief valve
No inserts	DOE 2016 Minimum Efficiency Compliant	Low voltage neutral copper ground strap from X0 to tank.	Dielectric Fluids -- Mineral Oil or Esters	
Primary bushing arrangement - standard per IEEE	No Switches on LV or HV	(2) Tank grounding connector (accepts #8 to #2 AWG conductor)	Grounding Clamps	
Secondary termination - Live front spade connectors	Wye-Wye connected HV and LV windings	Lifting lugs		
Seconary bushing arrangement - standard per IEEE	Radial or Loop feed arrangement in HV	IEEE PRV		
No fusing	Standard Impedance as per DOE	Nameplate		
No sectionalizing switches	4 terminals in LV (3 line terminals and Neutral)			
No arresters	Deadfront bushings in HV			
Oil fill provision - standard per IEEE	Livefront bushings in LV			
Oil drain provision - standard per IEEE	Full Capacity Windings HV and LV			
No gauges	No fusing or Secondary breaker protection			
Enclosure material - mild steel				
Markings - none				
Fluid - mineral oil				

Input for 3 Phase Pad Configurations

Regional Standard Accessories Configuration		
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Coastal/Stainless tank and hardware	Under oil arresters in HV	Stainless Steel cabinet and base
	Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)	All Stainless Steel Construction
	HV fusing with general purpose partial range current limiting fuse, internally mounted	
	Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	
	Special AWR ratings (55°C)	
	Special colors (Gray ANSI 70, Desert Tan)	

Standard Baseline Configuration				
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Single voltage primary (no Dual Voltage)	Pad-mount green color	Loop fed (6 primary bushings)	Pressure relief valve	High Voltage Bushings
Standard neutral configuration per IEEE	Standard pressure-relief system (PRV)	Protection (Bay-o-nets/ELSP)	Mineral Oil	Protection -- Fuse Cartridge
No taps	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	Coating system to meet IEEE, Green color		
Primary feed - loop	Standard decals/stencils for kVA Rating on Tank	Doors secured with bolt and provision for a padlock		
Primary termination - 35 kV, 200 amp bushing wells	Standard Nameplate inside compartment	Jack bosses or jacking provisions		
No inserts	Lifting Lugs	HV compartment on the left, LV compartment on the right. HV compartment can't be opened without opening		
Primary bushing arrangement - standard per IEEE (specific dimensions)	Nominal Percent Impedance as per IEEE Stds.	HV and LV compartments seperated by a barrier of metal or other rigid material		
Secondary termination - Live front spade connectors	Ground connector in tank	%Z per IEEE		
Seconary bushing arrangement - standard per IEEE (specific dimensions)	Altitudes of 1000 m (3300 ft) or less	65C Rise		
Bayonet fusing and isolation link	Standard Danger and Warning Safety Labels - NEMA 260	Minimum BIL ratings		
No sectionalizing switches	DE-energized tap changer with external operation	Parking Stands		
No arresters	Radial or Loop feed terminal arrangement	4 - secondary bushings, NEMA pads per IEEE		
Oil fill provision - standard per IEEE	Terminal arrangement as per compartment configuration of IEEE Stds.	Low voltage neutral copper ground strap from X0 to tank.		
Oil drain provision - standard per IEEE	Jacking facilities for lifting	(2) Tank grounding connector (accepts #8 to #2 AWG conductor)		
Liquid level indicator	Deadfront HV separable connectors (IEEE Std 386)	Lifting lugs		
Enclosure material - mild steel	Components for loop primary cable systems (IEEE Std 386) 200 A, 600 A or 900	IEEE PRV		
Markings - none	LV Terminals with supports	Nameplate		
Fluid - mineral oil	Lightning arrester attachment			
	Parking stands in HV compartment			

Input for 3 Phase Pad Configurations

Custom Utility Specific Configuration					
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Taps	Basic fusing (expulsion fuse in Bayonet with isolation link)	Tap changer ((2) +/- 2.5% taps)	External Bay-o-Net Fuse Compartment		HV Bushing wells
Dual voltage	Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)	Labeling unt with Company Stock number	7 position tap changer		HV Loop Feed
Impedance requirements	HV fusing with general purpose partial range current limiting fuse, internally mounted	Munsel Green # 7.0 GY3.29/1.5	35kV Under Oil Arresters	Protection -- Magnex Breakers	LV studs
Netural options	Plastic Drip shield for Bayonet	Maximum dimension of pad to be 72" x 72" to fit on standard concrete box pad.	12.47kV, 19.8kV and 24.9kV 750kVA and above and all sizes 35kV shall be	Secondary Arrester -- Internal/External MOV	Drain valve and sampler
Primary feed	HV Bushing inserts	Minimum size must fit over a 40" x 16" opening, fully covering opening.	All sizes 35kV shall have two, three phase, under oil, gang operated, load break "LOOP-TIE" switches.	Tap Changers (5 position, 7 Position)	Pressure relief valve
Primary terminations	Custom spade terminals mounted on LV bushings and mechanically supported	provisions for a 9/16" dia padlock. Hex bolts for securing bolts	Optical Liquid Level Gauge (if "ON-OFF" switches are required)	Dual Voltage Switches	HV bushing inserts
Secondary terminations	2 position HV Loadbreak switch	Manufacturered after 1979 sticker		4 Position Switches	LV terminations (spades or other)
Specific Bushing Layout	Dual Voltage switch standard 2:1 or 3:1 ratios	5/16" hole on right side of door for Company tag		Solid Insulation	Decals
Internal fusing	Special spacing and locations of components on front tank wall	Clearance and Warning stickers per Company design		Stainless Steel Tank/Hardware	Ground Clamps
ON/OFF loadbreak switches	Special BIL requirements in HV	5 legged design or 3 separate core assemblies		Internal Fault Detector	Bayonet fuse with Partial Range Current Limiting fuses
Sectionalizing loadbreak switches	Liquid Level Gauge	Eaton 4 position switch on primary side to de-energize transformer without "bliping" downstream customers.			Coil switch (on/off)
Arresters	Liquid Temperature Gauge	95kV BIL for 15kV, 150kV BIL for 35kV units		Vacuum Pressure Gauge	DeEnergized Tap Changer

Input for 3 Phase Pad Configurations

Custom Utility Specific Configuration					
Under Oil Arresters	Pressure/Vaccum gauge	Loop fed (6 primary bushings)		Drain valve with sampling	
Gauges		Protection (Bay-o-nets/ELSP)		Temperature Gauge	
Markings		Jack bosses or jacking provisions		LBOR Switches	
Fluid		HV compartment on the left, LV compartment on the right. HV compartment can't		Protection -- Isolation links	
Ground connectors		HV and LV compartments seperated by a barrier of metal or other rigid material			
Pressure relief devices		%Z per IEEE			
Coastal/Stainless tank and hardware		65C Rise			
Footprint Requirements		Parking Stands			
Shipping requirements		4 - secondary bushings, NEMA pads per IEEE			
		Low voltage neutral copper ground strap from X0 to tank.			
		(2) Tank grounding connector (accepts #8 to #2 AWG conductor)			
		Lifting lugs			
		IEEE PRV			
		Nameplate			

Input for 3 Phase Pad Configurations

Added Accessories or Features			
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Branding requirements	Special fusing with full range current limiting fuse with cannister fuse holder	Primary Bushing Inserts	Bayonet fuseing with partial range current limiting fuses
Ground connectors	LV Breaker	Warning/Notice Label	(3) 2-position switches for sectionalizing
Markings	Dual Voltage switch with odd ratios (fractional)	Danger Label	4-position switch
External protection (arresters/fuses)	Custom fuses in terminal board in HV	Option for Envirotemp FR3 fluid or equivalent	Lightning arresters
Primary terminations	4 position HV Loadbreak switch		Load break Feed-thru inserts
Secondary terminations	Special AWR (75°C), with high temperature insulating liquids (natural ester)		600 amp dead break bushings
	Custom Mechanical structures (Ducts, flanges, Throaths) for HV or LV connections		Thermometer
	Special LV terminals with number of holes above IEEE Stds., and customized mechanical support structures		Liquid Level Gauge
	Special BIL requirements in LV		Pressure Vaccuum gauge

Added Accessories or Features			
	K Factor (Design for Loads with high harmonic content)		35 kV load break integraal bushings
	Step-up operation		Live front Bushings
	Tap changers with more than 5 tap positions		Gauges with Contacts
	Special taps with more than 10% voltage range		Gauges, Switches, and Drain valves accesible from the Outside of Main cabinet but
	Pressure relief device		Less-flammable Natural Ester Fluid
	Liquid Level Gauge with alarm contacts		
	Liquid Temperature with alarm contacts		
	Pressure/Vaccum gauge with alarm contacts		
	Sudden Pressure Relay		
	Internal Fault Detector		

Working Documents from Meeting 11
February 14, 2024

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Agenda

Meeting Time: 90 minutes		
DOE	5 minutes	Welcome and introductions
USDA	15 minutes	RUS documents overview
All	65 minutes	Continue discussion of Configuration Matrix
DOE	5 minutes	Next steps

Discussion of Configuration Matrix

Configuration Matrix

- Outline target configurations ranging from minimum requirements to full customization from both the Manufacturer and Utility perspectives
- Impact to Manufacturing Lead Time based on Features

Minimal configuration to support transforming power safely.	Baseline configuration which includes minimal number of standard components to provide IEEE standard requirements and	Common custom specification to accommodate specific utility requests for configuration, component locations, and	Configuration to accommodate specific regional accessories or materials required. This should be similar to the Standard	These added Accessories or Features would be considered selected options that may intermittently impact the standard or custom
General Comments:	General Comments:	General Comments:	General Comments:	General Comments:
Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration	Regional Standard Accessories Configuration	Added Accessories or Features
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead

Input for 1 Phase OH Configurations

Minimalist Configuration	Standard Baseline	Custom Utility Specific
1 Phase Overhead	1 Phase Overhead	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)
Single Cooling rating 65°C AWR	Single Cooling rating 65°C AWR	Two sets of support lugs (RUS spec.)
No Switches on LV or HV	Dual Voltage switch standard 2:1 ratio	Lightning arresters & mounting bracket
No fusing or Secondary breaker protection	Optional Taps in HV winding, 2 above and 2 below, of 2.5%	Primary Bushing Creep Distance
Primary Bushing Rated for System Voltage	1 or 2 bushings in HV, 3 or 4 bushings in LV, livefront type	Current Limiting Fuse
Standard Impedance as per DOE	Minimum Impedance as per IEEE Stds.	Secondary terminations
Fluid - mineral oil	Dielectric Fluids -- Mineral Oil or Esters	Lightning Mitigation Design Considerations
Standard pressure-relief system (PRV)	Standard pressure-relief system (PRV)	Special BIL requirements in HV
Single Hanger Mounting	Single or Double Hanger Mounting	Under Oil Arresters
Nameplate	Standard Nameplate on support lug	Secondary circuit breaker protection with indictor light (CSP transformer)
	Cover grounding connection	4 Position Switches
	Tank grounding connector (accepts #8 to #2 AWG conductor)	Internal Fault Detector

Minimalist Configuration	Standard Baseline	Custom Utility Specific
		Vacuum Pressure Gauge
		15kV Insulated covers
		Required Impedance Ranges
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
		Expulsion fuse in HV
		Labeling / Branding Requirements
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		CSP units with LV Breaker
		HV breaker (Magnex)
		Wildlife protection
		Custom fuses in terminal board in HV

Input for 1 Phase Pad Configurations

Minimalist Configuration	Standard Baseline	Custom Utility Specific
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount
Mild Steel Tank with IEEE C57.12.28 Coating System	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	Dual Voltage switch standard 2:1 or 3:1 ratios
Tank and compartment with doors to prevent access to terminals and connections	Single Cooling rating 65°C AWR	HV fusing with general purpose partial range current limiting fuse, internally mounted
Single Cooling rating 65°C AWR	Radial or Loop feed terminal arrangement	Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
Primary bushing arrangement - standard per IEEE - TYPE 2 A	Primary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	Footprint Requirements
Seconary bushing arrangement - standard per IEEE - TYPE 2 A	Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	Fluid (Ester)
No Switches on LV or HV	Minimum Impedance as per IEEE Stds.	Tap Changers (5 position, 7 Position)
No taps in HV winding	Oil fill provision - standard per IEEE	Internal Fault Detector
Bayonet Fusing with Isolation Link	Oil drain provision - standard per IEEE	Special BIL requirements in HV
Minimum BIL ratings	Lifting provisions	Specific Bushing Layout
Pressure relief valve	LV ground connector and/or connection	Tap changer ((2) +/- 2.5% taps)
Standard Impedance as per DOE	Parking stands in HV compartment	provisions for a 9/16" dia padlock. Hex bolts for securing bolts
Fluid - mineral oil	Ground connector in tank	Clearance and Warning stickers per Company design

Minimalist Configuration	Standard Baseline	Custom Utility Specific
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount
Nameplate	Compliance with BIL and Dielectric Test Requirements	Loop fed (2 primary bushings)
	Protection (Bay-o-nets/ELSP)	Preapproved bushing inserts.
		Copper Oxide on door latch hardware
		Vacuum Pressure Gauge
		Ground Clamps
		Drain valve with sampling
		Protection -- Magnex Breakers
		4160x12kV Primary
		19.9kV Under Oil Arresters
		Plastic Drip shield for Bayonet
		LV in Line Terminals mounted on LV bushing studs
		Special spacing and locations of components on front tank wall

Minimalist Configuration	Standard Baseline	Custom Utility Specific
1 Phase Pad Mount	1 Phase Pad Mount	1 Phase Pad Mount
		Lightning arrester attachment
		Secondary Arrester -- Internal/External MOV
		Secondary connectors (zbars, covered/not covered)
		300 stainless steel sill
		Loadbreak ON/OFF switch
		Sectionalizing loadbreak switches
		Special AWR ratings (55°C)
		Special colors (Gray ANSI 70, Desert Tan)
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		Special fusing with full range current limiting fuse with cannister fuse holder
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
		Custom fuses in terminal board in HV
		Deeper Cabinet
		Thermometer
		Liquid Level Gauge
		DeEnergized Tap Changer

Input for 3 Phase Pad Configurations

Minimalist Configuration	Standard Baseline	Custom Utility Specific
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Mild Steel Tank with IEEE C57.12.28 Coating System	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof), and Coating System Performance)	Dual Voltage switch standard 2:1 or 3:1 ratios
Sealed tank construction with welded cover and bolted handhole	Coating system to meet IEEE, Green color	Tap changer ((2) +/- 2.5% taps)
Single voltage primary (no Dual Voltage)	Radial or Loop feed arrangement in HV	Full Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
Standard neutral configuration per IEEE	Ground connector in tank	HV fusing with general purpose partial range current limiting fuse, internally mounted
No taps	Standard Danger and Warning Safety Labels - NEMA 260	Impedance requirements
No Switches on LV or HV	DE-energized tap changer with external operation	Netural options
Secondary termination - Live front spade connectors	Jacking facilities for lifting	Specific Bushing Layout
Seconary bushing arrangement - standard per IEEE	Parking stands in HV compartment	Internal fusing
Primary feed - radial	Standard pressure-relief system (PRV)	ON/OFF loadbreak switches
Primary termination - 35 kV, 200 amp bushing wells	Nameplate	Sectionalizing loadbreak switches
No inserts	Bayonet fusing and isolation link	Arresters
Tank and compartment with doors to prevent access to terminals and connections	Mineral Oil	Under Oil Arresters
Minimum BIL	Primary termination - 35 kV, 200 amp bushing wells	5 legged design or 3 separate core assemblies

Minimalist Configuration	Standard Baseline	Custom Utility Specific
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
Oil fill provision - standard per IEEE	No inserts	Eaton 4 position switch on primary side to de-energize transformer without "bliping" downstream customers.
Oil drain provision - standard per IEEE	Primary bushing arrangement - standard per IEEE (specific dimensions)	95kV BIL for 15kV, 150kV BIL for 35kV units
No gauges	Secondary termination - Live front spade connectors	Special spacing and locations of components on front tank wall
Fluid - mineral oil	Seconary bushing arrangement - standard per IEEE (specific dimensions)	Custom spade terminals mounted on LV bushings and mechanically supported
Full Capacity Windings HV and LV	Terminal arrangement as per compartment configuration of IEEE Stds.	Plastic Drip shield for Bayonet
No fusing or Secondary breaker protection		HV compartment on the left, LV compartment on the right. HV compartment can't be opened without opening the LV compartment
Deadfront bushings in HV		HV and LV compartments seperated by a barrier of metal or other rigid material
Livefront bushings in LV		12-hole NEMA pads for secondary connectors
Single Cooling rating 65°C AWR		Fluid (Ester)
		VFI for 2000kVA and up
		Supplied with Primary bushings.
		Preapproved bushing inserts.
		Copper Oxide on door latch hardware
		Vacuum Pressure Gauge
		Drain valve with sampling
		Temperature Gauge
		Internal Fault Detector
		Coil switch (on/off)
		4160x12kV Primary
		Secondary Arrester -- Internal/External MOV

Minimalist Configuration	Standard Baseline	Custom Utility Specific
3 Phase Pad Mount	3 Phase Pad Mount	3 Phase Pad Mount
		Tap Changers (5 position, 7 Position)
		4 Position Switches
		Solid Insulation
		Special spacing and locations of components on front tank wall
		Liquid Level Gauge
		provisions for a 9/16" dia padlock. Hex bolts for securing bolts
		Manufacturered after 1979 sticker
		Clearance and Warning stickers per Company design
		Partial Stainless Steel Tank and compartment enclosure (Grades 304 or 409)
		Special AWR ratings (55°C)
		Special colors (Gray ANSI 70, Desert Tan)
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		Branding requirements
		Special fusing with full range current limiting fuse with cannister fuse holder
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
		Custom Mechanical structures (Ducts, flanges, Throaths) for HV or LV connections
		Special LV terminals with number of holes above IEEE Stds., and customized mechanical support structures
		K Factor (Design for Loads with high harmonic content)

Discussion of Critical Components

Identification of Critical Components and Accessories

- Identify components and accessories that might impact lead times and deliveries
- Develop a list for further investigation to support reduction in lead times and standardization

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments	Comments
Protection -- Bayonet Fuses	RTE/EATON COOPER BAY-O-NET FUSES DUAL SENSING W/DRIP SHIELDS & OIL RETAINING VALVES & ISOLATION LINKS	15		5	Components used are sourced from overseas by supplier. Some are Sole Sourced (Hi-Amp family)	We have standardized on Cooper Power Dual-Sensing Bay-O-Net fuses for most sizes of single-phase and 3-phase padmounted transformers.
Protection -- Current Limiting	35kV transformers, Three RTE oil Bay-O-Net with load sensing fuses in series with back up ELSP current limiting fuses	9		6	Critical component for transformers that utilize internal protection for high fault current applications. Component parts sourced from overseas by supplier. Fuses with similar ratings across manufacturers are not necessarily interchangeable, have to be individually coordinated against transformer and smaller fuse selection. Highly specified component from end users.	We have standardized on Cooper Power ELSP current-limiting backup fuses on 3-phase padmounted transformers.
Bayonet Assembly or Fuse Holders	Cooper Bay-O-Net fuses, DS indicates Dual Sensing Bay-O-Net fuse, HA indicates High Ampere Overload Bay-O-Net fuse	16		7	Critical component for padmount transformers that utilize internal protection. Production constraints.	Cooper Power sidewall-mounted Bay-O-Net on single-phase and 3-phase padmounted transformers.
Protection -- Isolation links	PER ABOVE LI#1	17		10	Critical component for padmount transformers that utilize bayonet fusing. Production constraints	Required on single-phase padmounted transformers.
Protection -- Magnex Breakers & LV Breakers	N/A	3	Single Source and long lead times	12	Single Source	Not required on OH or UG transformers.
Protection -- Fuse Cartridge	PER ABOVE LI#1	11		8		Cooper Power Bay-O-Net
Primary Arresters -- Normal Duty/Heavy Duty	N/A Separate Accessory Installed by Utility	1	LT over 1 year on special purpose models that are from single source	4	Extremely high market demand across manufacturers over last few years with growth in overhead demand. High number of SKU's for various configurations.	UG: Elbow arresters (not currently using bushing arresters or parking stand arresters). OH: Heavy duty/riser pole, tank-mounted. Arresters are purchased and stocked separate from transformers for both OH and UG.
Primary Arresters -- Under Oil	N/A	5		11	Optional accessory, application can be achieved through other means.	Not required on OH or UG transformers.
Secondary Arrester -- Internal/External MOV	N/A	8		17	Optional accessory that can be installed in field.	Not required on OH or UG transformers.
Tap Changers (5 position, 7 Position)	N/A	6		9	Critical component for transformers that includes adjustable taps. 7-position tap changers sole sourced and considered non-standard. 5-position considered default tap changer. Contact shortages at supplier.	Not required on OH or UG transformers.
Dual Voltage Switches	N/A	7		2	Critical component for dual voltage designs. Contact shortages at supplier.	Required on all OH and UG transformers aside from a small number of specialty units. Our system is predominately 14.4/24.9kV, but some areas are still 7.2/12.47kV.
4 Position Switches	N/A	2	Single Source and long lead times	1	Sole source. Contact shortages at supplier. Optional accessory, application can be achieved through other means.	Not required on OH or UG transformers.
LBOR Switches	35 kV Cooper Power Catalog Number 2200912C21M or equivalent	4	Typically with long lead times	3	Critical component for transformers that include internal load break switching. Contact shortages at supplier.	Not required on OH or UG transformers.

Identification of Critical Components and Accessories

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments	Comments
LBOR Switches	35 kV Cooper Power Catalog Number 2200912C21M or equivalent	4	Typically with long lead times	3	Critical component for transformers that include internal load break switching. Contact shortages at supplier.	Not required on OH or UG transformers.
High Voltage Bushings	35kV Small Elastimold Interface	10		14		OH: Cover mounted (single-bushing configuration for single transformer installations; dual-bushing for banks). UG: bushing wells with 25kV Class 200A loadbreak bushing inserts installed; arrangement in three-phase units as shown in Figure 16 of IEEE C57.12.34.
Low Voltage Neutral Bushings	Secondary bushings with threaded studs and screw on terminals are NOT acceptable. All secondary bushings with 8 holes or greater must be equipped with external supports.	12		15		UG single-phase: Threaded stud. UG three-phase: NEMA pad with ground strap installed.
Bushing Wells	35kV Small Elastimold Interface	13		19		Yes
15kV Insulated covers	N/A Separate Accessory Installed by Utility	14		29		?
Stainless Steel Tank/Hardware	Stainless steel hinges and stainless steel pins (type 304) shall be provided	19		27		UG: single-phase all-stainless (tank, lid and sill); 3-phase stainless cabinet and hardware - mild steel tank and fins. OH: stainless cover and cover band.
Internal Fault Detector	Single Source	18		13	Single Source	Not required on OH or UG transformers.
Pressure Relief Valves	Yes	21		25		Required on OH and UG transformers.
Oil Level Indicators	Yes	27		23	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Dielectric Fluids -- Mineral Oil or Esters	Non-PCB Mineral Oil	29		22		Less-flammable fluid required on three-phase UG units; single-phase UG and OH units may use mineral oil or less-flammable fluid.
Solid Insulation	N/A	20		21		Not required on OH or UG transformers.
Grounding Clamps	HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ ENTERPRISES AS1409-005.	23		16	Optional accessory that can be installed in field.	Threaded transformer grounding clamp
Animal guards	N/A Separate Accessory Installed by Utility	28		20	Optional accessory that can be installed in field.	Purchased and stocked separate from transformer.
Creep Bushings	N/A	22		18		I'm not familiar with this term. If it refers to specifying a bushing with a higher than standard creepage distance, we do not do this.
Vacuum Pressure Gauge	Larger kVA's	26		28	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Drain valve with sampling	Yes	24		26		Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Temperature Gauge	Yes	25		24	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.

Agenda

Meeting Time: 90 minutes		
DOE	7 minutes	Welcome
DOE	8 minutes	FITT FOA
DOE	20 minutes	DT information dissemination
All	50 minutes	Continue discussion of Configuration Matrix
DOE	5 minutes	Next steps

Working Documents from Meeting 12
March 6, 2024

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

FITT FOA

Flexible and Innovative Transformer Technologies (FITT) FOA

- The objective of this Funding Opportunity Announcement (FOA) is to advance the research, development, and **demonstration** (RD&D) of advanced transformers (e.g., flexible, modular, scalable, hybrid, and solid-state transformers) that can be readily utilized across a range of distribution to transmission scale applications.

- This FOA has **two** Area of Interests that seek to address the technical challenges of advancing the current state of transformers in the US power grid. Under this FOA, DOE is specifically interested in Research, Development, and Demonstration (RD&D) applications for Distribution (Area of Interest 1) and Power Transformers (Area of Interest 2).

- **A field demonstration of a relevant technology, power or distribution transformer is required – this should be no less than 25% of the project scope.**

Discussion of Configuration Matrix

Configuration Matrix

- Outline target configurations ranging from minimum requirements to full customization from both the Manufacturer and Utility perspectives
- Impact to Manufacturing Lead Time based on Features

Minimal configuration to support transforming power safely.	Baseline configuration which includes minimal number of standard components to provide IEEE standard requirements and	Common custom specification to accommodate specific utility requests for configuration, component locations, and	Configuration to accommodate specific regional accessories or materials required. This should be similar to the Standard	These added Accessories or Features would be considered selected options that may intermittently impact the standard or custom
General Comments:	General Comments:	General Comments:	General Comments:	General Comments:
Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration	Regional Standard Accessories Configuration	Added Accessories or Features
1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead	1 Phase Overhead

Input for 1 Phase OH Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Overhead		
Tank and Cooling		
Single Cooling rating 65°C AWR	Altitudes of 1000 m (3300 ft) or less	
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	Special AWR ratings (55°C, 75°C)
Sealed tank construction with bolted on cover	Lifting means	Stainless Steel Tank and/or covers (Grades 304 or 409)
Single Hanger Mounting	Single or Double Hanger Mounting	
Standard Dielectric Fluid	Fluid - Mineral Oil	Dielectric Fluids -- Mineral Oil or Esters
Electrical Rating		
Non-Interlaced Windings	Interlaced windings on core type (50kVA and smaller)	Interlaced windings on shell type (50kVA and smaller)
DOE Min. Efficiency Compliant		Required Impedance Ranges
DOE Standard Impedance	Minimum Impedance as per IEEE	Special BIL requirements in HV
Minimum BIL ratings		Optional Taps in HV winding, 2 above and 2 below, of 2.5%
No taps		Dual Voltage Primary
Single Voltage Primary		
Components		
Standard pressure-relief system	Pressure Relief Valve (PRV)	Dual Voltage Switches
No switches LV or HV	Standard Nameplate on support lug	Primary Bushing Creep Distance
No fusing or Secondary breaker protection	Standard decals/stencils for kVA Rating on Tank	Secondary terminations
1 or 2 HV cover mounted bushings w/ clamp type terminals	Insulated cover	15kV Insulated covers
Primary Bushing Rated for System Voltage	Cover grounding connection	Current Limiting Fuse
3 LV side mounted bushings w/ clamp type terminals (except 167kVA)	Tank ground connector (accepts #8 to #2 AWG conductor)	CSP units with LV Breaker
	De-energized tap changer with external operation	HV breaker (Magnex)
	Low voltage neutral copper ground strap from X2 to tank.	Expulsion fuse in HV
	Lightning arrester mounting provision	Lightning arresters & mounting bracket
		Custom fuses in terminal board in HV
		Wild life protectors on HV bushings and arresters
		Labeling / Branding Requirements
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)

Input for 1 Phase Pad Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Pad Mount		
Tank and Cooling		
Single Cooling rating 65°C AWR	Altitudes of 1000 m (3300 ft) or less	Special AWR ratings (55°C, 75°C)
Mild Steel Tank with IEEE C57.12.28 Coating System	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof)	Stainless Steel Tank/Hardware (Grades 304 or 409)
Tank and compartment with doors to prevent access to terminals and connections		Special spacing and locations of components on front tank wall / Specific Bushing Layout
Standard Dielectric Fluid	Fluid - Mineral Oil	Dielectric Fluids -- Mineral Oil or Esters
		Special colors (Gray ANSI 70, Desert Tan)
		Deeper Cabinet
		Footprint Requirements
Electrical Rating		
Non-Interlaced Windings	Interlaced windings on core type (50kVA and smaller)	Interlaced windings on shell type (50kVA and smaller)
Primary 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 A	Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
Non-Interlaced Windings	Loop feed terminal arrangement	Radial or Loop feed terminal arrangement
DOE Min. Efficiency Compliant		Loop feed (2 primary bushings)
DOE Standard Impedance	Minimum Impedance as per IEEE Stds.	
Minimum BIL ratings	Compliance with BIL and Dielectric Test Requirements	
No taps in HV winding		Optional Taps in HV winding, 2 above and 2 below, of 2.5%
Single Voltage Primary		Dual Voltage Primary
		Special BIL requirements in HV
Protection		
Bayonet Fusing with Isolation Link		
		Protection -- Magnex or Secondary Breakers
		Under Oil Arresters
		Lightning arrester attachment
		Secondary Arrester -- Internal/External MOV
		HV fusing with general purpose partial range current limiting fuse, internally mounted
		Special fusing with full range current limiting fuse with cannister fuse holder
		Custom fuses in terminal board in HV

Input for 1 Phase Pad Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
Components		
No Switches on LV or HV		Dual Voltage switch standard 2:1 or 3:1 ratios
2 Universal HV bushing wells		De-energized Tap Changer
3 Secondary bushings supplied with copper studs per IEEE (5/8" for 25-75kVA, 1" for 100 to 167kVA)		Loadbreak ON/OFF switch
No Switches on LV or HV		Sectionalizing loadbreak switches
		LV in Line Terminals mounted on LV bushing studs
		Secondary connectors (zbars, covered/not covered)
		Preapproved bushing inserts.
Pressure relief valve (PRV)		
	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/danger, Customer ID numbers, Barcode Labels)
		Thermometer
		Liquid Level Gauge

Input for 3 Phase Pad Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Pad Mount		
Tank and Cooling		
Single Cooling rating 65°C AWR	Altitudes of 1000 m (3300 ft) or less	Special AWR ratings (55°C, 75°C)
Mild Steel Tank with IEEE C57.12.28 Coating System	Compliance with IEEE C57.12.28 Enclosure Integrity (Mechanical (Tamper proof)	Stainless Steel Tank/Hardware (Grades 304 or 409)
Tank and compartment with doors to prevent access to terminals and connections		Special spacing and locations of components on front tank wall / Specific Bushing Layout
Standard Dielectric Fluid	Fluid - Mineral Oil	Dielectric Fluids -- Mineral Oil or Esters
		Special colors (Gray ANSI 70, Desert Tan)
		Deeper Cabinet
		Footprint Requirements
Electrical Rating		
Non-Interlaced Windings	Interlaced windings on core type (50kVA and smaller)	Interlaced windings on shell type (50kVA and smaller)
Primary 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 A	Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
Non-Interlaced Windings	Loop feed terminal arrangement	Radial or Loop feed terminal arrangement
DOE Min. Efficiency Compliant		Loop feed (2 primary bushings)
DOE Standard Impedance	Minimum Impedance as per IEEE Stds.	
Minimum BIL ratings	Compliance with BIL and Dielectric Test Requirements	
No taps in HV winding		Optional Taps in HV winding, 2 above and 2 below, of 2.5%
Single Voltage Primary		Dual Voltage Primary
		Special BIL requirements in HV
Protection		
Bayonet Fusing with Isolation Link		
		Protection -- Magnex or Secondary Breakers
		Under Oil Arresters
		Lightning arrester attachment
		Secondary Arrester -- Internal/External MOV
		HV fusing with general purpose partial range current limiting fuse, internally mounted
		Special fusing with full range current limiting fuse with cannister fuse holder
		Custom fuses in terminal board in HV

Input for 3 Phase Pad Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
Components		
No Switches on LV or HV		Dual Voltage switch standard 2:1 or 3:1 ratios
2 Universal HV bushing wells		De-energized Tap Changer
3 Secondary bushings supplied with copper studs per IEEE (5/8" for 25-75kVA, 1" for 100 to 167kVA)		Loadbreak ON/OFF switch
No Switches on LV or HV		Sectionalizing loadbreak switches
		LV in Line Terminals mounted on LV bushing studs
		Secondary connectors (zbars, covered/not covered)
		Preapproved bushing inserts.
Pressure relief valve (PRV)		
	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/danger, Customer ID numbers, Barcode Labels)
		Thermometer
		Liquid Level Gauge

Configuration Matrix Next Steps

- Core Configuration Categories Agreement
- Impact to Manufacturing Lead Time based on Features
  - Design time
  - Design Tradeoffs
  - Manufacturing Lead time
  - Raw material inventory
  - Associated component lead time
  - Opportunities for Automation, Poke-Yoke, Inventory reduction, etc.
- Core Configuration impact to Interchangeability Matrix input

Working Documents from Meeting 13
March 27, 2024

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Agenda

Meeting Time: 90 minutes		
DOE	5 minutes	Welcome
DOE	10 minutes	Next Steps of Configuration Matrix
All	55 minutes	Discussion of Configuration Impact and Critical Components
All	10 minutes	Identification of Critical Components and Accessories
DOE	10 minutes	Next steps

Next Steps of Configuration Matrix

Configuration Matrix Next Steps

- Core Configuration Categories Agreement
- Impact to Manufacturing Lead Time based on Features
  - Design time
  - Design Tradeoffs
  - Manufacturing Lead time
  - Raw material inventory
  - Associated component lead time
  - Opportunities for Automation, Poke-Yoke, Inventory reduction, etc.
- Core Configuration impact to Interchangeability Matrix input

Manufacturer – Configuration Matrix

- Labor hours required to build a design:
  - Based on final configuration breakdown of minimalist as a baseline
  - Target most meaningful custom items for manufacturing impact
    - Dual voltage transformers
    - Load break switches
    - Taps
    - Live front arrestors/Special purpose arrestors
    - Odd turns ratio
    - ???

	Minimalist Configuration	Opportunities for Scale or Automation Improvement	Standard Configuration	Opportunities for Scale or Automation Improvement	Custom Utility Specific Configuration	Opportunities for Scale or Automation Improvement
Single Phase Overhead	Baseline		+ % labor hours		+ % labor hours	
Single Phase Pad	Baseline		+ % labor hours		+ % labor hours	
Three Phase Pad	Baseline		+ % labor hours		+ % labor hours	

- Overall considerations:
  - Percentage increase in manufacturing time
  - Percentage increase/decrease in manufacturing capacity
  - Opportunities for impact at scale, automation, raw material inventory, etc.
  - Design trade-offs for balance of efficiency, SWaP, and inventory

Manufacturer – Configuration Matrix

- Additional considerations:
  - Impact of reduction of SKU and line changeover
  - Estimation of percentage change in Cost
- Supply chain impacts are very dynamic
  - Clarify components to be omitted, substituted, traded-off, etc.
  - Direct component lead time impact to manufacturer delivery not considered for this exercise
  - Identify any direct technical barriers (sole source, economy of scale, technology limitations)
  - Critical components and accessories list and baseline estimates

Utilities – Configuration Matrix

- Impact of streamlining the configurations
  - What would it take to get agreement and acceptance?
  - Trade-offs for design, inventory, and procurement strategy
  - Could an Inventory of Configurations with Dual Voltage and Taps be used more for utilization in emergency or mutual assistance situations?
  - Input on forecast for new installations, replacements, and electrification
    - Demand Forecast
    - Capacity Forecast

Discussion of Critical Components

Identification of Critical Components and Accessories

- Identify components and accessories that might impact lead times and deliveries
- Develop a list for further investigation to support reduction in lead times and standardization

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments	Comments
Protection -- Bayonet Fuses	RTE/EATON COOPER BAY-O-NET FUSES DUAL SENSING W/DRIP SHIELDS & OIL RETAINING VALVES & ISOLATION LINKS	15		5	Components used are sourced from overseas by supplier. Some are Sole Sourced (Hi-Amp family)	We have standardized on Cooper Power Dual-Sensing Bay-O-Net fuses for most sizes of single-phase and 3-phase padmounted transformers.
Protection -- Current Limiting	35kV transformers, Three RTE oil Bay-O-Net with load sensing fuses in series with back up ELSP current limiting fuses	9		6	Critical component for transformers that utilize internal protection for high fault current applications. Component parts sourced from overseas by supplier. Fuses with similar ratings across manufacturers are not necessarily interchangeable, have to be individually coordinated against transformer and smaller fuse selection. Highly specified component from end users.	We have standardized on Cooper Power ELSP current-limiting backup fuses on 3-phase padmounted transformers.
Bayonet Assembly or Fuse Holders	Cooper Bay-O-Net fuses, DS indicates Dual Sensing Bay-O-Net fuse, HA indicates High Ampere Overload Bay-O-Net fuse	16		7	Critical component for padmount transformers that utilize internal protection. Production constraints.	Cooper Power sidewall-mounted Bay-O-Net on single-phase and 3-phase padmounted transformers.
Protection -- Isolation links	PER ABOVE LI#1	17		10	Critical component for padmount transformers that utilize bayonet fusing. Production constraints	Required on single-phase padmounted transformers.
Protection -- Magnex Breakers & LV Breakers	N/A	3	Single Source and long lead times	12	Single Source	Not required on OH or UG transformers.
Protection -- Fuse Cartridge	PER ABOVE LI#1	11		8		Cooper Power Bay-O-Net
Primary Arresters -- Normal Duty/Heavy Duty	N/A Separate Accessory Installed by Utility	1	LT over 1 year on special purpose models that are from single source	4	Extremely high market demand across manufacturers over last few years with growth in overhead demand. High number of SKU's for various configurations.	UG: Elbow arresters (not currently using bushing arresters or parking stand arresters). OH: Heavy duty/riser pole, tank-mounted. Arresters are purchased and stocked separate from transformers for both OH and UG.
Primary Arresters -- Under Oil	N/A	5		11	Optional accessory, application can be achieved through other means.	Not required on OH or UG transformers.
Secondary Arrester -- Internal/External MOV	N/A	8		17	Optional accessory that can be installed in field.	Not required on OH or UG transformers.
Tap Changers (5 position, 7 Position)	N/A	6		9	Critical component for transformers that includes adjustable taps. 7-position tap changers sole sourced and considered non-standard. 5-position considered default tap changer. Contact shortages at supplier.	Not required on OH or UG transformers.
Dual Voltage Switches	N/A	7		2	Critical component for dual voltage designs. Contact shortages at supplier.	Required on all OH and UG transformers aside from a small number of specialty units. Our system is predominately 14.4/24.9kV, but some areas are still 7.2/12.47kV.
4 Position Switches	N/A	2	Single Source and long lead times	1	Sole source. Contact shortages at supplier. Optional accessory, application can be achieved through other means.	Not required on OH or UG transformers.
LBOR Switches	35 kV Cooper Power Catalog Number 2200912C21M or equivalent	4	Typically with long lead times	3	Critical component for transformers that include internal load break switching. Contact shortages at supplier.	Not required on OH or UG transformers.

Identification of Critical Components and Accessories

Critical Components and Accessories	Comments	Qualitative Ranking for Leadtime Impact	Comments	Qualitative Ranking for Leadtime Impact	Comments	Comments
LBOR Switches	35 kV Cooper Power Catalog Number 2200912C21M or equivalent	4	Typically with long lead times	3	Critical component for transformers that include internal load break switching. Contact shortages at supplier.	Not required on OH or UG transformers.
High Voltage Bushings	35kV Small Elastimold Interface	10		14		OH: Cover mounted (single-bushing configuration for single transformer installations; dual-bushing for banks). UG: bushing wells with 25kV Class 200A loadbreak bushing inserts installed; arrangement in three-phase units as shown in Figure 16 of IEEE C57.12.34.
Low Voltage Neutral Bushings	Secondary bushings with threaded studs and screw on terminals are NOT acceptable. All secondary bushings with 8 holes or greater must be equipped with external supports.	12		15		UG single-phase: Threaded stud. UG three-phase: NEMA pad with ground strap installed.
Bushing Wells	35kV Small Elastimold Interface	13		19		Yes
15kV Insulated covers	N/A Separate Accessory Installed by Utility	14		29		?
Stainless Steel Tank/Hardware	Stainless steel hinges and stainless steel pins (type 304) shall be provided	19		27		UG: single-phase all-stainless (tank, lid and sill); 3-phase stainless cabinet and hardware - mild steel tank and fins. OH: stainless cover and cover band.
Internal Fault Detector	Single Source	18		13	Single Source	Not required on OH or UG transformers.
Pressure Relief Valves	Yes	21		25		Required on OH and UG transformers.
Oil Level Indicators	Yes	27		23	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Dielectric Fluids -- Mineral Oil or Esters	Non-PCB Mineral Oil	29		22		Less-flammable fluid required on three-phase UG units; single-phase UG and OH units may use mineral oil or less-flammable fluid.
Solid Insulation	N/A	20		21		Not required on OH or UG transformers.
Grounding Clamps	HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ HUBBELL (FARGO), Bronze grounding connector, catalog number GC – 207 or HJ ENTERPRISES AS1409-005.	23		16	Optional accessory that can be installed in field.	Threaded transformer grounding clamp
Animal guards	N/A Separate Accessory Installed by Utility	28		20	Optional accessory that can be installed in field.	Purchased and stocked separate from transformer.
Creep Bushings	N/A	22		18		I'm not familiar with this term. If it refers to specifying a bushing with a higher than standard creepage distance, we do not do this.
Vacuum Pressure Gauge	Larger kVA's	26		28	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Drain valve with sampling	Yes	24		26		Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.
Temperature Gauge	Yes	25		24	Optional accessory	Required on three-phase UG transformers and single-phase and three-phase stepdown transformers.

Interchangeability Matrix

Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 1Ph, etc.	KVA	Fuse, Sticker, MOV	Protection, Marking							Only to expedite	Completely interchangeable	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
1 Phase Pad	All kva	Pressure Relief Valves		Qualitrol		Beta		Hoerland			Completely interchangeable				No
1 Phase Pad	All kva	Bay-o-net assembly		Cooper		ABB					Completely interchangeable				No
1 Phase Pad	All kva	Bay-o-net fuse holders		Cooper		ABB					Completely interchangeable				No
1 Phase Pad	All kva	Bay-o-net Fuse		ERMCO		Cooper		ABB			Completely interchangeable				No
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C04						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C10						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C12						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C14						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C17						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C06						Completely interchangeable				
1 Phase Pad		Bayonet Fuse	Protection	Cooper	4000353C08						Completely interchangeable				
1 Phase Pad	All	Secondary Terminations	Connectors	HOMAC	2308 SUS IRSW 2308 SUS L					Any Zber type set-screw	Any Zber type set-screw	Similar build/installation	Verification of being equal		Yes
1 Phase Pad	All	Primary Bushing Wells	Bushing Well	Eaton	BWI 50R	Eaton	26383 72C02R			Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		No
1 Phase Pad	All	Primary Bushing Wells	Clamp Bushing Well	Eaton	2085 99A01	Kuhlman	42102 12-006			Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		No
1 Phase Pad	All	Bushing Inserts	Inserts	Elastimold	1601 A4	Eaton	1R215	Hubbell	5U02AA8001	Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		Yes
1 Phase Pad	All	Fuse Cartridge	Bayonet Fuse	Eaton	3437922802M					Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		No
1 Phase Pad	All	Tank Grounding	Grounds	Penn Union	LSN-050N EIAM					Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		Yes
1 Phase Pad	All	Fuses	Protection	See Fuse Table						Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		No
1 Phase Pad	All kva	Transformer Tank Bronze Ground Clamps		H-J Enterprises, Inc.		Kearney		Penn Union			Completely interchangeable				No
1 Phase Pad	All kva	Bushing Wells 125kV BIL		Elastimold		ERMCO		ABB			Completely interchangeable				No
1 Phase Pad	All kva	Low Voltage/Neutral Bushings		Cooper		Central Moloney		ABB			Completely interchangeable				Yes
1 Phase Pad	All kva	Current Limiting Fuse		Cooper		GE/Mersen		Hi-Tech			Completely interchangeable				No
1 Phase Pad		Sticker	Marking	Almetek	17261						Completely interchangeable				
1 Phase Pad		Sticker	Marking	Almetek	17262						Completely interchangeable				

Need more details

Confirming configuration and part number inputs

Correlated to Critical Components Matrix

Interchangeability Matrix

Type:	Size	Primary Component	Category	Manufacturer	Model #	Manufacturer	Model #	Manufacturer	Model #	Short Term Only	Long Term	Performance	Quality	Other	Aftermarket Option
OH, 3Ph, etc.	kV A	Fuse, Sticker, MOV	Protection, Marking							Only to expedite	Completely interchangeable	Critical matching requirements	Test specs or other metrics		Ability to add at Utility
1 Phase Pad	All kva	Bushing Wells 15/kV BIL		Elastimold		Central Moloney		Howard			Completely interchangeable				No
1 Phase Pad	All kva	Bay-o-net oil drip shields		Central Moloney		Howard		RTE (Cooper)			Completely interchangeable				No
1 Phase Pad	All kva	Fiber Optic Oil Level Indicator (15.5kV units)		Trayer		Heartland					Completely interchangeable				No
1 Phase Pad	All kva	Non-PCB Label		Almetek		LEM					Completely interchangeable				No
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE03						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE06						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE10						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE12						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE18						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE25						Completely interchangeable				
1 Phase Pad		Magnox	Protection	Cooper	MX1AE1SYE30						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD803C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD804C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD805C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD806SC100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD810C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD812SC100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD815SD100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD808C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUCD816SD100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUC2803C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUC2805C100						Completely interchangeable				
1 Phase Pad		ELSP	Protection	Cooper	CBUC2808C100						Completely interchangeable				
1 Phase Pad		Magnox Hardware Kit	Protection	Cooper	9638595A08						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV125						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV135						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV014						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV019						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV0256						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV0108						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV0102						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV0029						Completely interchangeable				
1 Phase Pad		Magnox Shunt Kit	Protection	Cooper	MXOV0025						Completely interchangeable				
1 Phase Pad	All	Dielectric Fluid	Ester Fluids	Cargil	FR3	Midel	1215			Prior Approval	Prior Approval	Similar build/installation	Verification of being equal		No

Need more details

Confirming configuration and part number inputs

Correlated to Critical Components Matrix

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Working Documents from Meeting 14
April 24, 2024

U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Agenda

Meeting Time: 90 minutes		
DOE	5 minutes	Welcome
DOE	30 minutes	Transformer efficiency standards
All	30 minutes	Configuration Matrix – Manufacturer Input
DOE	10 minutes	Next steps

Efficiency standards

Configuration Matrix – Manufacturer Input

Manufacturer – Configuration Matrix

- Labor hours required to build a design:
  - Based on final configuration breakdown of minimalist as a baseline
  - Target most meaningful custom items for manufacturing impact
    - Dual voltage transformers
    - Load break switches
    - Taps
    - Live front arrestors/Special purpose arrestors
    - Odd turns ratio
    - ???

	Minimalist Configuration	Opportunities for Scale or Automation Improvement	Standard Configuration	Opportunities for Scale or Automation Improvement	Custom Utility Specific Configuration	Opportunities for Scale or Automation Improvement
Single Phase Overhead	Baseline		+ % labor hours		+ % labor hours	
Single Phase Pad	Baseline		+ % labor hours		+ % labor hours	
Three Phase Pad	Baseline		+ % labor hours		+ % labor hours	

- Overall considerations:
  - Percentage increase in manufacturing time
  - Percentage increase/decrease in manufacturing capacity
  - Opportunities for impact at scale, automation, raw material inventory, etc.
  - Design trade-offs for balance of efficiency, SWaP, and inventory

Manufacturer – Configuration Matrix

- Additional considerations:
  - Impact of reduction of SKU and line changeover
  - Estimation of percentage change in Cost
- Supply chain impacts are very dynamic
  - Clarify components to be omitted, substituted, traded-off, etc.
  - Direct component lead time impact to manufacturer delivery not considered for this exercise
  - Identify any direct technical barriers (sole source, economy of scale, technology limitations)
  - Critical components and accessories list and baseline estimates

Manufacturer Input – Configuration Matrix

- Initial feedback:
  - Transformer labor scales with kVA size and some component installation may be uniform over large kVA range
    - Potential for Larger % impact on small kVA vs. larger kVA designs
  - Dual Voltage and taps
    - Switch wiring and installation
      - Installation at about 10min per deck – Taps and Even DV ratios typically use one deck (1ph) and three decks (3ph)
      - Odd DV rations can nearly double the installation time due to multi deck switches
    - Coil Winding – 30% labor reduction is feasible when reducing dual voltage to single voltage or eliminating taps
  - Opportunities for scale and automation
    - Feasibility to consolidate to single core/coil design for given single system voltage
      - Every unique tap or dual voltage creates new design requirement

Manufacturer Input – Configuration Matrix

Initially identified as most impactful

	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 Overhead	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 Overhead	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 taps vs Taps ((2) +/- 2.5%)	4%			
Single Phase Pad	Baseline	Single Voltage HV			Dual Voltage in HV	6%
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 Pad	Baseline	No arrester			Under Oil Arresters	3%
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%

Manufacturer Input – Configuration Matrix

Initially identified as most impactful

	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
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%