Distribution Service Transformer Sub-Group on Standardization Opportunities

Topics for Configuration Matrix Deliverable

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

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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 Subgroup Input)

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			

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

Topics for Action resulting from attribute consolidation

Topics resulting from the Attribute and kVA Sizing/Frequency

- 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

Action 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

Consider a Configuration Matrix

- 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

Configuration Matrix – Request for Information from Combined Subgroup

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

Consolidated Input for 1 Phase OH Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
1 Phase Overhead		
Mild Steel Tank with IEEE C57.12.28 Coating System		
	ANSI #24 (dark gray) or ANSI #70 (light gray) paint. Coating system to meet IEEE	
		Stainless Steel Tank and/or covers (Grades 304 or 409)
No Switches on LV or HV		
	Dual Voltage switch standard 2:1 ratio	
	Optional Taps in HV winding, 2 above and 2 below, of 2.5%	
		4 Position Switches
No fusing or Secondary breaker protection		
		Current Limiting Fuse
		CSP units with LV Breaker
		HV breaker (Magnex)
		Secondary circuit breaker protection with indictor light (CSP transformer)
		Expulsion fuse in HV
		Under Oil Arresters
		Lightning arresters & mounting bracket
		Lightning Mitigation Design Considerations
		Custom fuses in terminal board in HV
Single Cooling rating 65°C AWR		
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
Fluid - mineral oil		
	Dielectric Fluids -- Mineral Oil or Esters	

Consolidated Input for 1 Phase OH Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
Standard Impedance as per DOE		
	Minimum Impedance as per IEEE Stds.	
		Required Impedance Ranges
Single Hanger Mounting		
	Single or Double Hanger Mounting	
		Two sets of support lugs (RUS spec.)
Primary Bushing Rated for System Voltage		
	1 or 2 bushings in HV, 3 or 4 bushings in LV, livefront type	
		Secondary terminations
		Primary Bushing Creep Distance
Standard pressure-relief system (PRV)		
	Cover grounding connection	
	Tank grounding connector (accepts #8 to #2 AWG conductor)	
		Internal Fault Detector
		Vacuum Pressure Gauge
		15kV Insulated covers
		Wildlife protection
		Special BIL requirements in HV
Nameplate		
	Standard Nameplate on support lug	
		Labeling / Branding Requirements
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)

Consolidated Input for 1 Phase Pad Configurations

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

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Consolidated Input for 1 Phase Pad Configurations

Minimalist Configuration	Standard Baseline Configuration	Custom Utility Specific Configuration
Primary bushing arrangement - standard per IEEE - TYPE 2 A		
Seconary bushing arrangement - standard per IEEE - TYPE 2 A		
	Primary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
	Seconary bushing arrangement - standard per IEEE - TYPE 2 or TYPE 1	
		Specific Bushing Layout
		Loop fed (2 primary bushings)
		Preapproved bushing inserts.
Single Cooling rating 65°C AWR		
Fluid - mineral oil		
		Fluid (Ester)
		Special AWR ratings (55°C)
		Special AWR (75°C), with high temperature insulating liquids (natural ester)
Minimum BIL ratings		
Standard Impedance as per DOE		
	Compliance with BIL and Dielectric Test Requirements	
	Minimum Impedance as per IEEE Stds.	
		Special BIL requirements in HV

Pressure relief valve		
Nameplate		
	Oil fill provision - standard per IEEE	
	Oil drain provision - standard per IEEE	
	Lifting provisions	
	LV ground connector and/or connection	
	Parking stands in HV compartment	
	Ground connector in tank	
		Internal Fault Detector
		provisions for a 9/16" dia padlock. Hex bolts for securing bolts
		Clearance and Warning stickers per Company design
		Copper Oxide on door latch hardware
		Vacuum Pressure Gauge
		Ground Clamps
		Drain valve with sampling
		Plastic Drip shield for Bayonet
		Custom markings (decals or stencils: Non PCB, warning, Customer ID numbers, Barcode Labels)
		Thermometer
		Liquid Level Gauge

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Consolidated Input for 3 Phase Pad Configurations

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

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Consolidated Input for 3 Phase Pad Configurations

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

Consolidated Input for 3 Phase Pad Configurations

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

Configuration Matrix – Input from Manufacturers

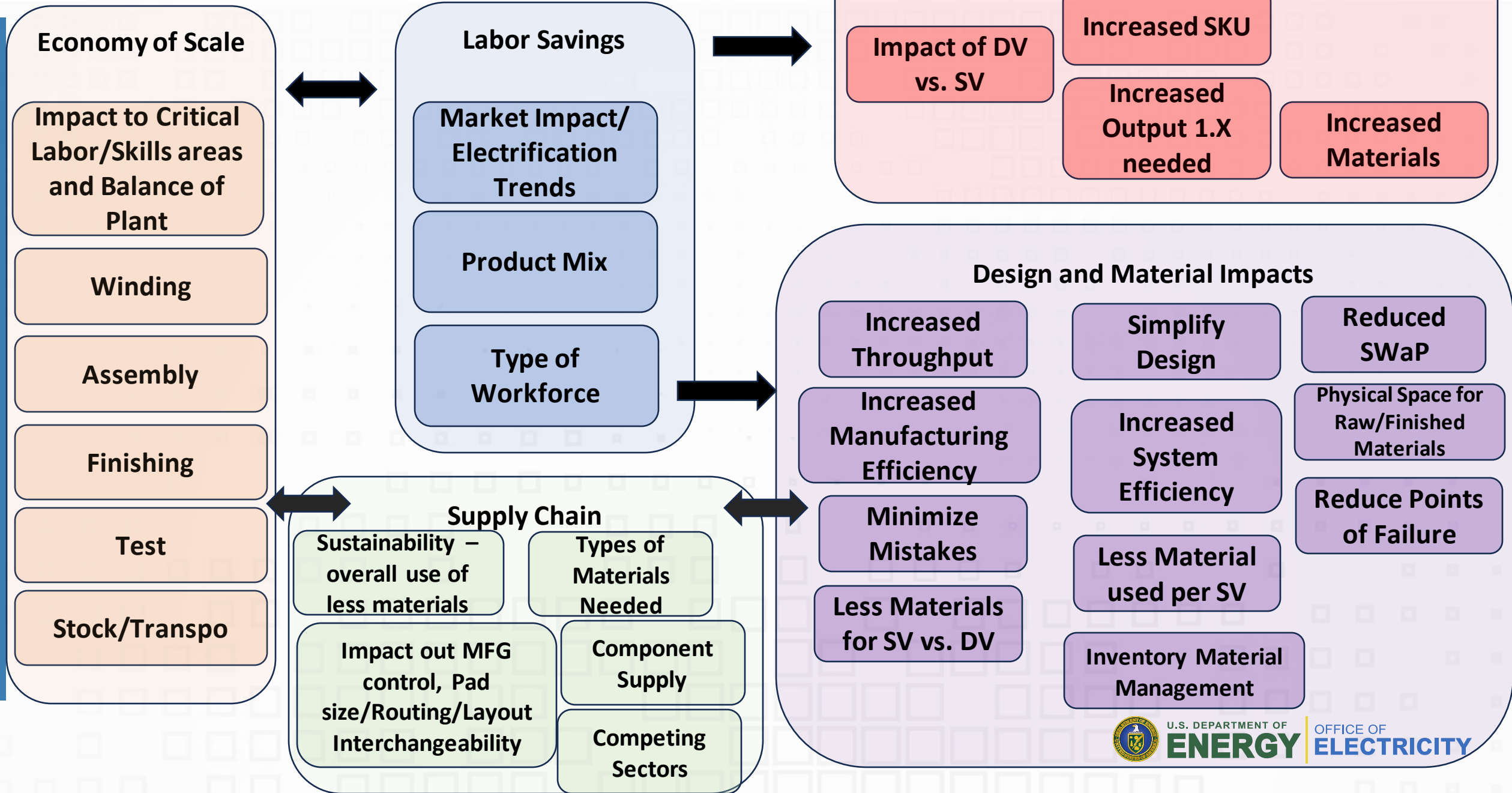
Manufacturer – Configuration Matrix

- 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

Input from Manufacturers



Manufacturer Input – Configuration Matrix

	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

	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%

Manufacturer Input – Configuration Matrix

Labor Savings

- Highest impact to labor areas
  - Dual Voltage Switches/Taps/Load break
  - CSP and Complex Fusing
  - Pad Mount Variations
  - Paint Color/Coatings

- Dual Voltage Switches (Labor impacts)
  - In general, the impact directly to labor ranges on the order of 5-15% with current product mix
    - Currently, the DV product mix assumed between 10-20% of market
    - If this product mix shifts toward DV, this impact would grow significantly
  - Voltage Ratio makes significant difference on the impact to labor and capacity
    - The higher the ratio the higher the impact on the winding and assembly times
  - Primary impacts and constraints to the Winding and Assembly areas
    - Winding areas impacted by DV, Taps, and Load Break Switch adders
    - Coil Winding is very specialized
  - Require more skilled workforce for the winding and switch installation
  - Overall estimated increase in capacity would be on the order of 10%
    - For an estimated 100K/year factory, estimate between 6-10K additional units

Manufacturer Input – Configuration Matrix

Labor Savings

- Pad Mount Variations
  - Small Size Variations for given pad mount class
    - Utility requirements for pad size, incoming service layouts, etc.
  - Front Plate Pad interconnection
    - Variation in bushing sizes and spacing requirements
    - No standardization on fuse placement
    - Difficult to build ahead or utilize for mutual assistance
- Paint/Coatings
  - Custom Paint (Desert Tan, Gray inside/out)
    - Separate base coats required
    - Selective coatings
  - Partial Stainless steel
  - Some vendors not offering/no quoting options

Manufacturer Input – Configuration Matrix

Design and Material Impacts

- Dual Voltage Switches (Design and Materials Impact)
  - Requirement to design for highest loss connection
    - Lower efficiency and space utilization
    - Lead to larger overall size for tank, amount of oil, size of wire, compactness of core, etc.
      - Increased size and weight
      - More materials used so could limit availability for additional units
    - Higher number of components and interconnections which leads to higher opportunities for failure
    - Could result in overdesign of leads and insulation requirements
    - Reduced fusing requirements
  - Impact to the Material availability
  - Supply chain limits on the availability of Dual Voltage Switches

Manufacturer Input – Configuration Matrix

NEGATIVE USAGE IMPACTS

- Dual Voltage Switches (Usage Impacts)
  - Impact of switching from Dual Voltage to Single Voltage
    - Possible increase in the number of SKUs
    - Potential for increased number of transformers needing to be produced
      - Potential for 1.X number of transformers needed to accommodate for both single voltage values
    - Increase in the overall material required

Manufacturer Input – Configuration Matrix

- General Input
  - Single Phase Pole mount orders appear to be leveling or softening (Catching up/ Lower Demand/Foreign Supply)
  - Transition from Pole to Pad requirements (Underground, EV Charging, larger kVA)
  - Increased requests for large kVA 3 phase for electrification
- Materials Limitations
  - Still tight supply chain for standard materials
    - Electrical steel is improving if the current forecasts hold
    - Transition to Amorphous needs to be strategic
  - Components particularly for high power still constrained
  - Conductors are becoming more difficult
    - Need for larger conductors
    - Competition with EV and other markets
    - Both Aluminum and Copper

Manufacturer Input – Configuration Matrix

Economy of Scale

- Economy of Scale
  - Each manufacturer has an optimal number of units for run size
    - This optimal number may be for queueing material, sub-assembly, material feed, or combined batch/automation processes
  - Number of Units Manufactured/Design – increasing this value improves the overall efficiency of the manufacturing – seen 10-20% improvement in capacity
  - High variation in critical operation areas
    - Winding
    - Assembly