
Impact of Standards on Magnetics Design Choices and Material Options

Presented at APEC, March 19th, 2025

Veda Samhitha Duppalli
Principal Design Engineer – Power Electronics



Outline

1. Introduction of CorePower Magnetics
2. Existing Standards overview and relevance for Magnetics
3. Impact of Standards on MV Inductor/Transformer Design
4. Summary



Driving Magnetification™ Forward...

Leading High Power Magnetic Component Manufacturing



Company Profile and Overview

- Established in 2020, now serving Fortune 200 companies
- Headquarters: Energy Innovation Center, Pittsburgh, PA
- Markets include transportation, grid, industrial, and commercial
- Exclusive Licenses from Carnegie Mellon University & National Energy Technology Laboratory
- Pilot Scale Manufacturing 10,000 sq. ft: January 2025
- Full Scale Manufacturing 100,000 sq. ft: Site Selection Q1 2025



Core Technology and Product Lines

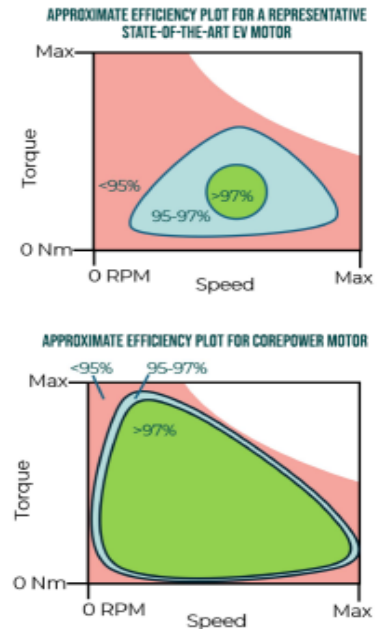
Next Generation Magnetics... Optimized Performance

Passives (Inductors and Transformers)



- Microgrids
- Electric Vehicle Charging
- Renewable and DER Integration

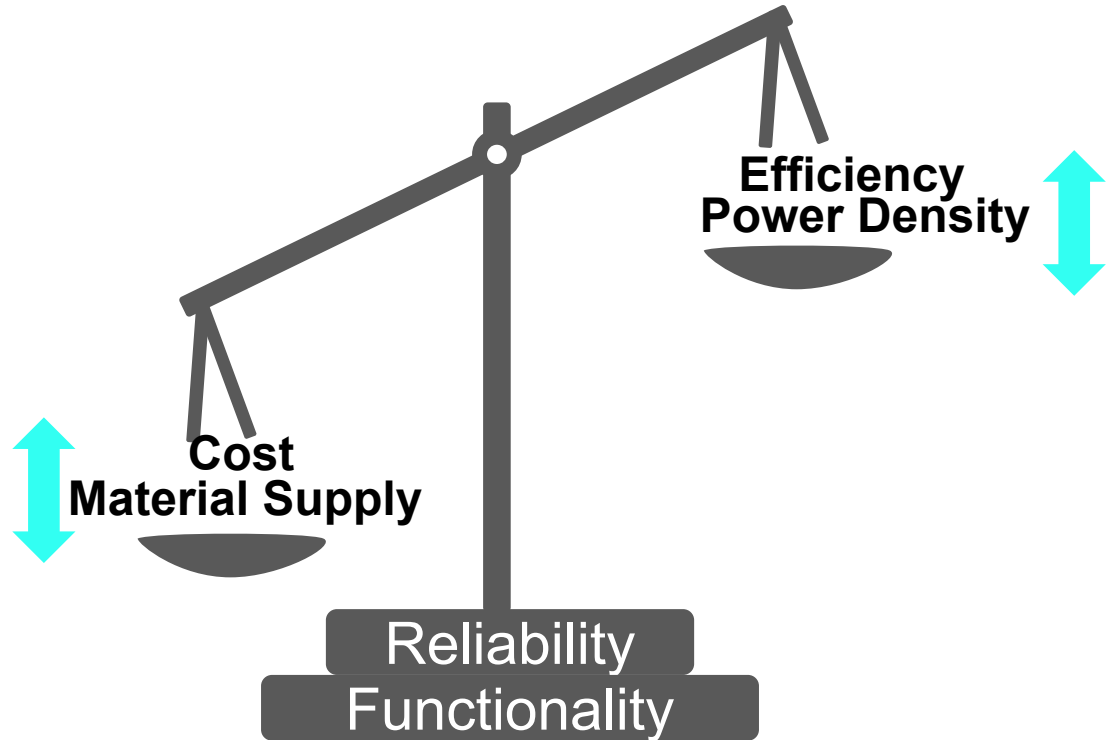
Electric Motors



- Electric Vehicles
- Data Center Thermal Management
- Auxiliary (Rail, Aviation, Construction)

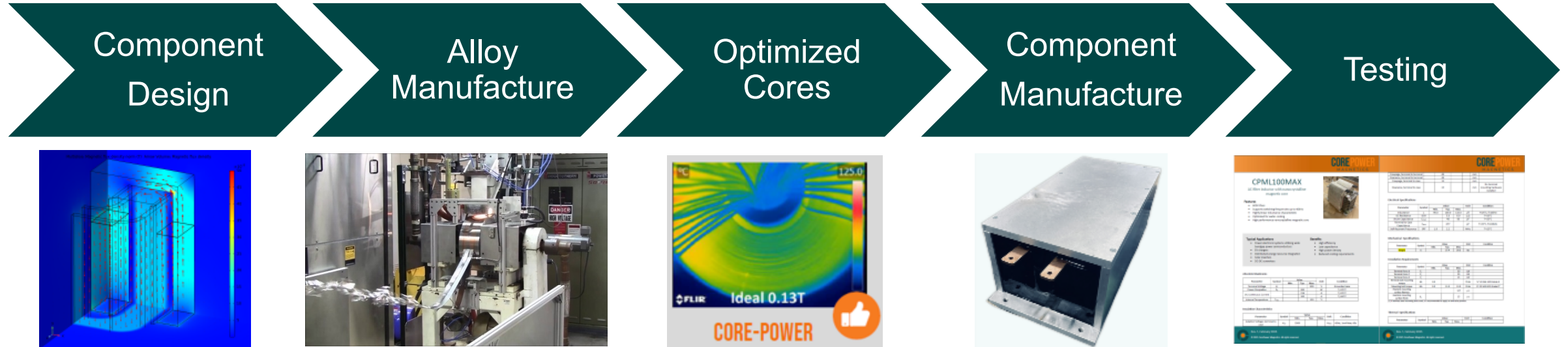


Magnetics in Power Electronics: Competing Metrics



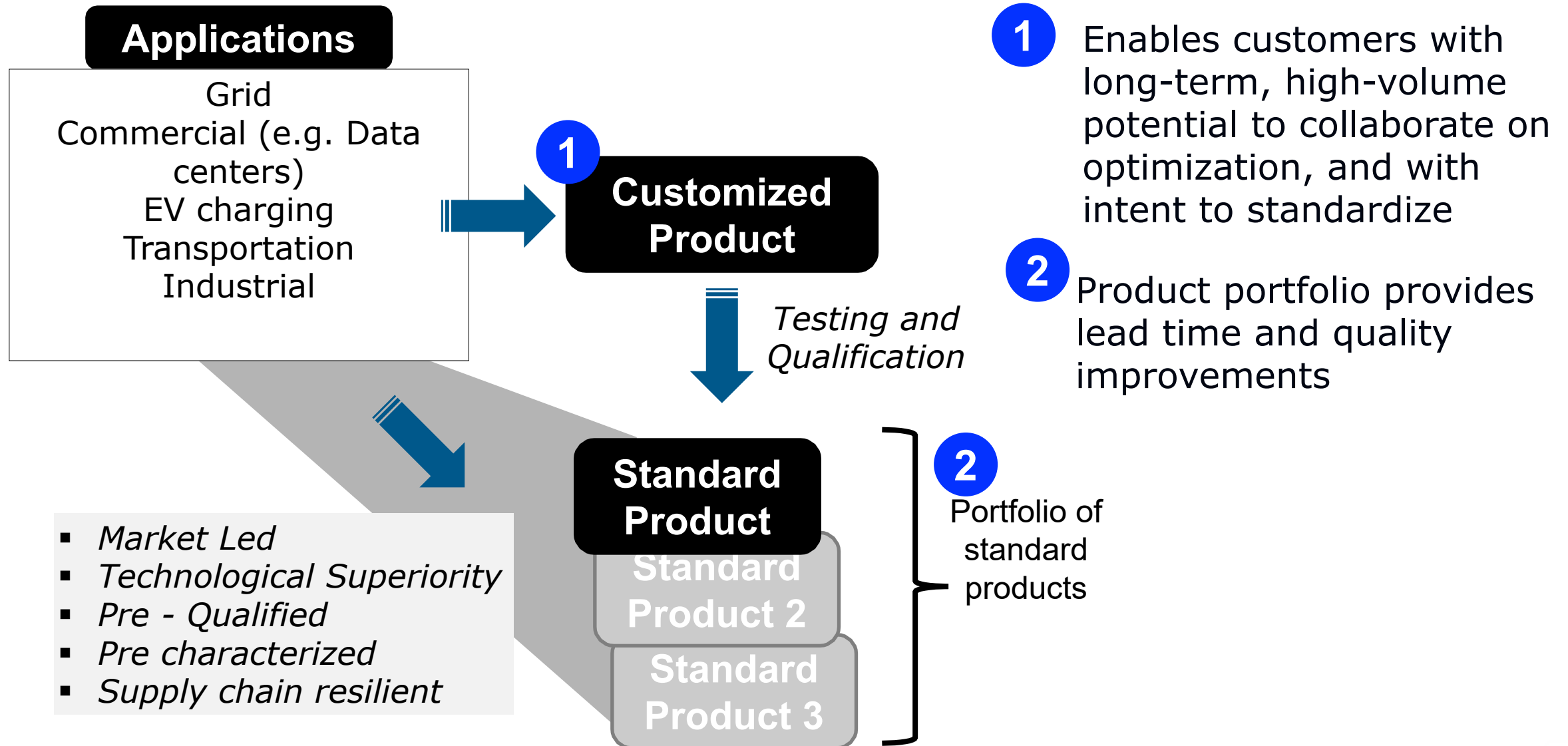
- Minimizing losses and maximizing power density are often seen as **competing goals** during the design phase.
- **Cost and materials supply** are essential factors in manufacturing.
- Optimizing efficiency, power density, cost and manufacturing while **ensuring functionality and reliability** is crucial, as these factors compete with one another.

Vertical Manufacturing: from Alloy-to-Component



- Novel inductor and transformer designs to maximize benefits of proprietary alloys
- In-house alloy manufacturing and processing capability
- Scalable and Controllable in-line core manufacturing
- Manufacture inductors and transformers using large-scale manufacturing methods
- Fully characterized components using in-house testing

Custom Product Success Through Standards & Qualification



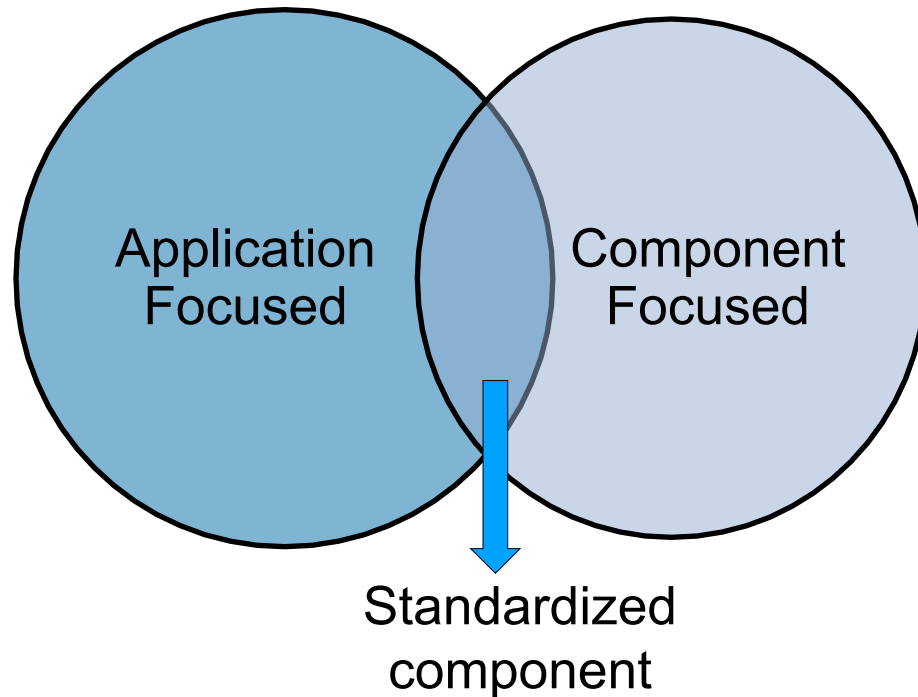
Outline

1. Introduction of CorePower Magnetics
- 2. Existing Standards overview and relevance for Magnetics**
3. Impact of Standards on Inductor/Transformer Design
4. Summary



Standards - Product Qualification

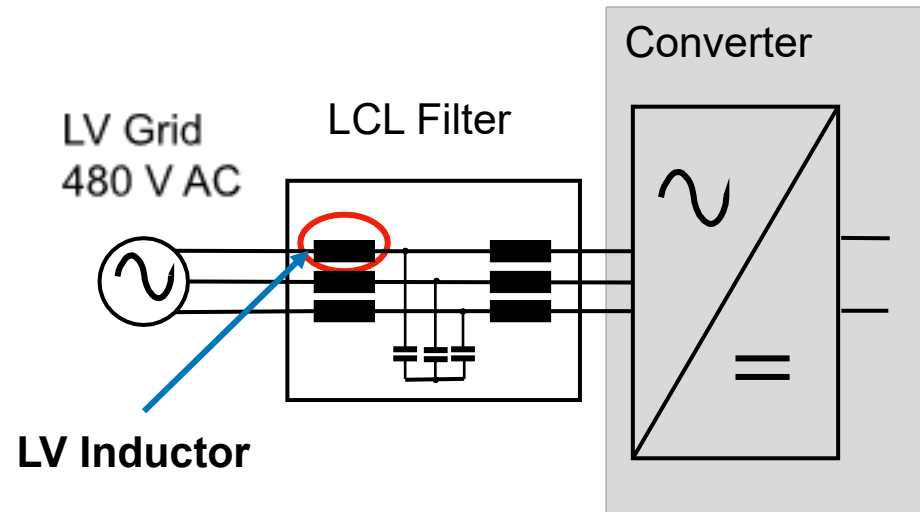
IEC, IEEE and UL standards are reviewed.



- Standardized inductor/transformer products must adhere to both application-specific and component-specific standards.
- Further categorization of standards include design, safety, testing and certification.

LV Inductor Example for Filter Application

Application: Inverter output low pass filter, connecting to LV grid



Inductor Specifications
Supporting converter operation

Current rating at 60Hz
Inductance
Switching frequency
Ripple frequency
Overload current
Cooling
Thermal class rating
Resonant frequency
Parasitic capacitance
Isolation Voltage

How to certify and qualify the LV inductor as standard component?

LV Inductor Example: Application Focused Standards

Here is an example of two applications where LV inductor can be used.

EV Supply Equipment

- IEC 61851-23
 - Isolating transformer insulation
 - IEC 61558 safety standard
- UL 2202
Transformer insulation design and tests

Distributed Energy Resources

- IEEE 1547
Inductance Spec
- IEEE 1662
PE system grounding
And Isolation
- UL 1741
 - UL 5085
 - UL 506

Application-focused standards establish relevant product focused standards and/or specify any additional requirements.



LV Inductor Example - Component Focused Standards

Insulation Coordination

- Insulating Materials
 - UL 1446
 - IEC 61857-1
- Creepage and Clearance
 - UL 840

Insulation coordination rating influences materials selections.

Safety Standards

- UL 5085
 - LV transformers
- IEC 61558

In scope for operation at
Line frequency with <1kHz switching

Environmental

IEC 60068

Testing

IEEE 389

Focused on
Electronic systems
LV rating

Essential to extend these standards to medium/high frequency and high-power operation.



LV Inductor Standardized Product Example

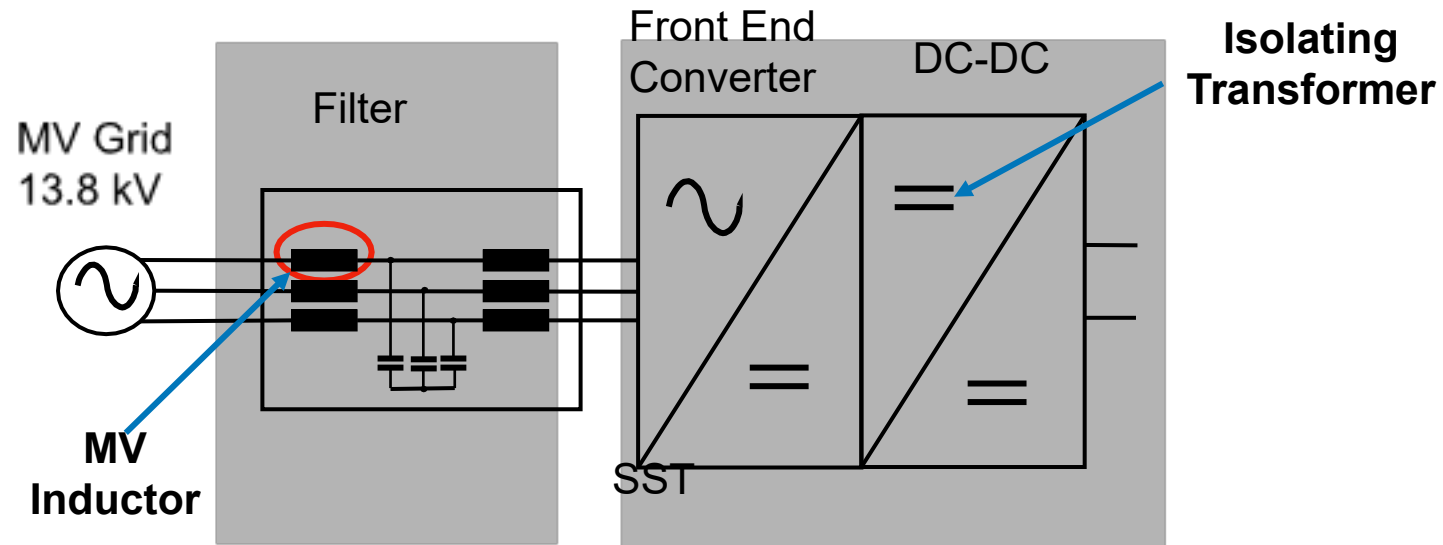
Target Specifications	CPML100MAX
Inductance	100uH
Current Rating	180 A RMS
Voltage rating	Up to 600 V RMS
Switching Frequency	Up to 40kHz
Switching ripple	Up to 50A pk-pk
Thermal Class Rating	Class H
Isolation rating	2.5 kV RMS
Cooling	Optimized for Liquid Cooling

Application & Component focused standards are being reviewed currently

Applications
Microgrids
Electric Vehicle Charging
Renewable and DER Integration
Data Centers



MV Inductor and DC-DC Transformer for SST Application



MV Considerations – Application and Component Focused Standards

- P3105 aims include recommend Standardized testing procedures for SST based transformers.
- Existing standards that are used – IEEE C57.12.xx

IEEE C57.12.01

- Voltage rating – AC line voltage rating, AC overvoltage, Lightning impulse
- Partial Discharge
- Temperature class rating
- Terminations
- Service life and reliability

+

- High switching frequency voltages
- dvdt

- UL 1562 – Transformer, Distribution, Dry-type - Over 600V
- IEC 60076 1-16 – Power transformer

Lets discuss IEC 60076-3 – Power transformers - Part 3 next.



Impact of Standards on Magnetics Design

Reference to IEC 60076-3 – (Power transformers - Part 3) Insulation levels, dielectric tests and external clearances in air

Table 4 – Insulation levels based on North American practice

Dielectric insulation levels for dry type transformers used on system with BILs 200 kV and below												
Max LL system voltage kV	Nominal LL system voltage kV	Low frequency voltage insulation level kV r.m.s.	Basic Lightning Impulse Insulation Levels (BILs) in common use (peak value 1,2 μs)									
			10	20	30	45	60	95	110	125	150	200
0,25	0,25	2,5	None									
0,6	0,6	3	S	1	1							
1,2	1,2	4	S	1	1							
2,75	2,5	10		S	1	1						
5,6	5	12			S	1	1					
9,52	8,7	19				S	1	1				
15,5	15	34					S	1	1			
18,5	18	40					S	1	1			
25,5	25	50						2	S	1	1	
36,5	34,5	70								2	S	1
Impulse chopped wave: minimum time to flash over (μs)			1	1	1	1,3	2	2	1,8	2	2,3	2,7
S = Standard values. 1 = Optional higher levels where exposure to overvoltage occurs and higher protective margins are required. 2 = Lower levels where surge arrester protective devices can be applied with lower spark-over levels.												

- AC line voltage = 13.8kV
- Low frequency voltage insulation level = 34 kV RMS
- BIL voltage peak level = 95 kV

How do insulation voltage levels impact the transformer and inductor design?



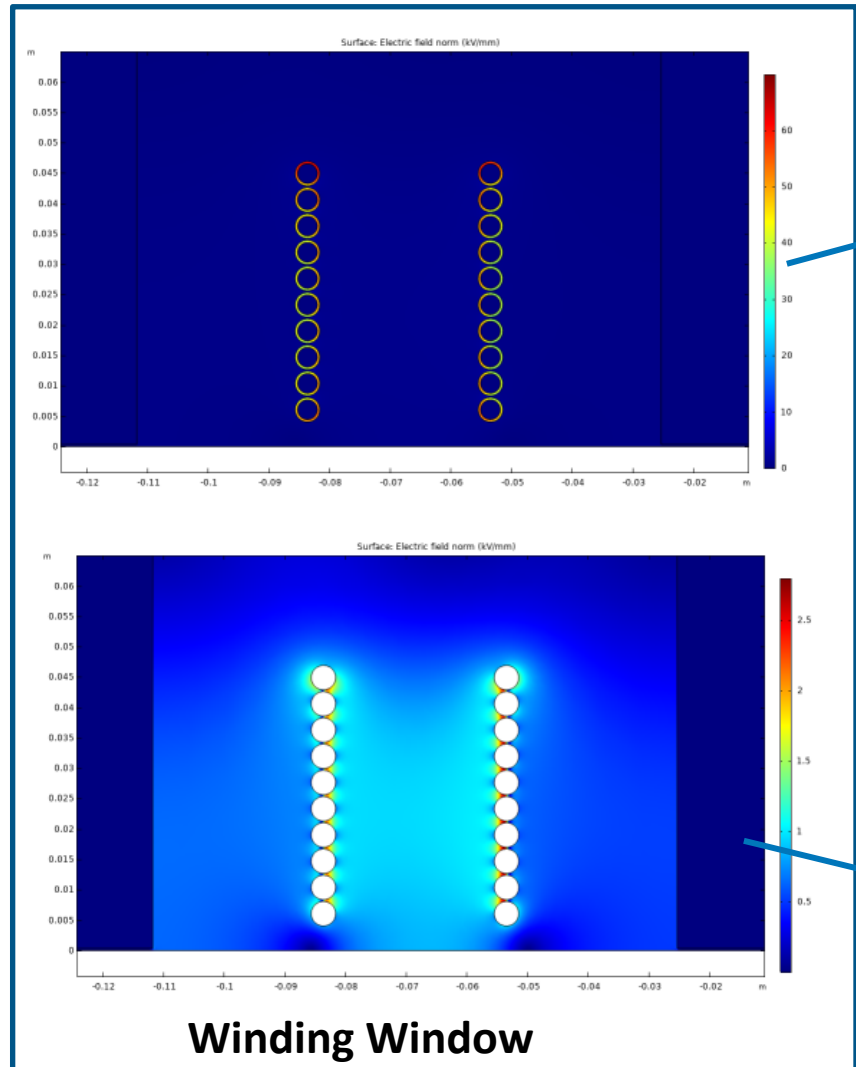
Outline

1. Introduction of CorePower Magnetics
2. Existing Standards overview and relevance for Magnetics
- 3. Impact of Standards on Inductor/Transformer Design**
4. Summary



Impact of Standards on Magnetics Design: DC-DC transformer

Electric field analysis (using FEA) is used to design insulation coordination system for 34kV RMS



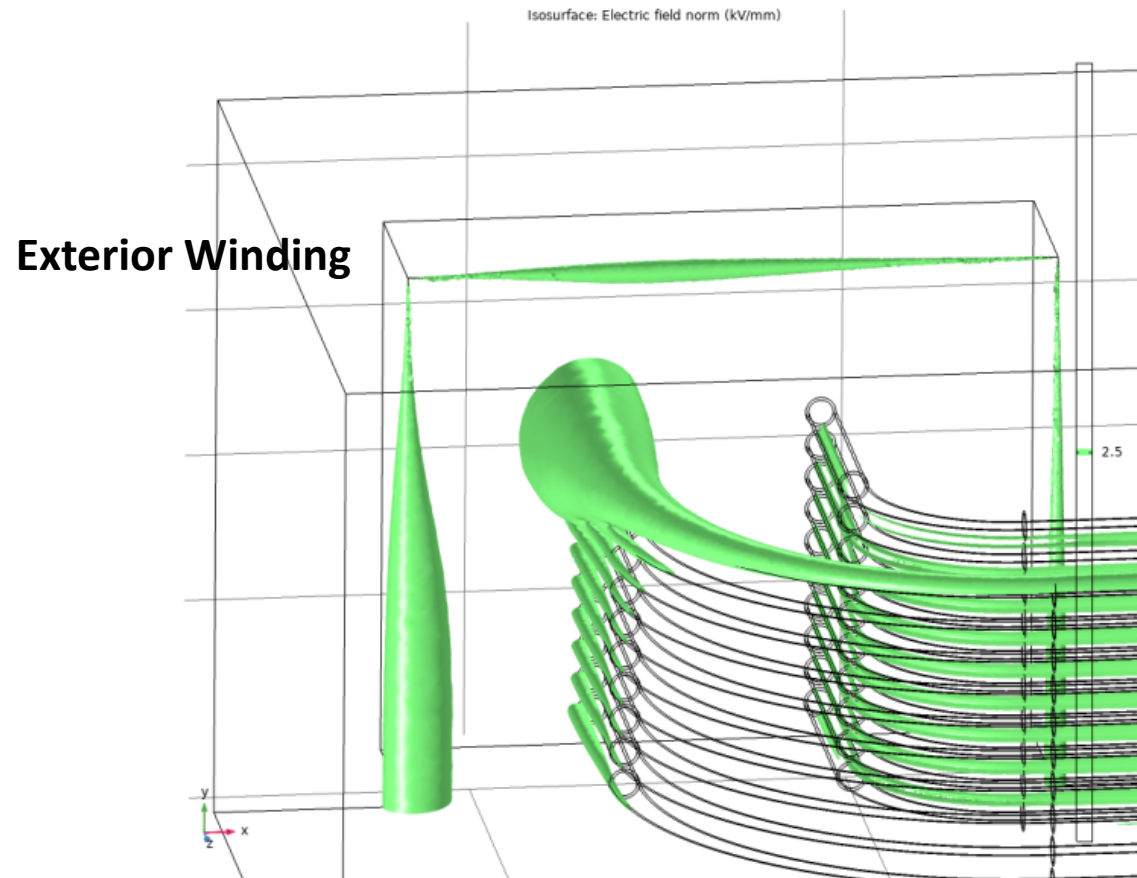
Winding
with FEP
insulation

Winding
without wire
insulation

- Peak voltage excitation between coils
- Location of Electric field peaks are observed to limit below material properties with margin.
- Not only break down voltage, permittivity differences in combination of insulating materials at play

Impact of Standards on Magnetics Design: DC-DC transformer

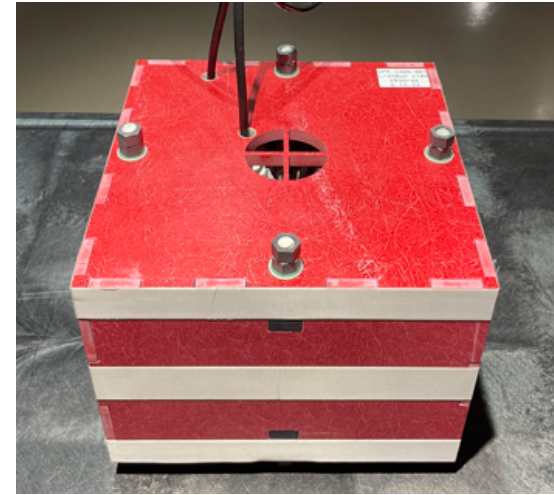
Electric field analysis (using FEA) is used to design insulation coordination system for 34kV RMS



E-Field iso-surface shows stress at the winding and core corner.

MV Inductor Example - Standardized tests

- Grid Side filter inductor for MV 13.8 kV
- Developed as part of ARPA-E SCALEUP
- Using CorePower proprietary technology
 - Gap less core
 - Isolation spacing for air cooling
- Collaborating with NREL for MV application relevant testing - Currently in the stage of functionality tests
- In-house MV rating capable component testing includes Hipot and PD, in accordance with
 - IEEE C57.12.91
 - IEEE C57.124



250 μ H, 83 A RMS at 60Hz



In-house MV Hipot testing

Summary

- Magnetics for high-power and medium/high frequency applications are often **custom designed**.
- CPM seeks to **standardize set of products** that are typically custom to support fast growth of power electronics.
- Standards play critical role in the design, manufacturing and testing of magnetic components. **Application and component focused standards** guide standardization approach – **identification of specs** and **testing and qualification** of the standard product.
- Standards for **line frequencies transformers** are often referred because of **robust guidelines** on design, testing and safety details.
- Particular to high-power, medium/high frequency, and MV applications, **developments of relevant standards** will be essential for standardized offerings for SSTs.



Thank you!

By, Veda Samhitha Duppalli

Email: veda.Duppalli@corepowermagentics.com

IS07 – The transformer in the Solid-State Transformer





Application focused Standards Examples – EVSE and SSTs

Standard	Description	Key Focus	Relevance to Magnetics
IEC 61851-23	Electric Vehicle Conductive Charging System - Part 23: DC Electric Vehicle Supply Equipment	Defines the standards for DC charging equipment for electric vehicles	Highlights Isolating transformer insulation needs in EV supply equipment, refers to IEC 61558 safety standard
UL 2202	Standard for Safety for Electric Vehicle (EV) Charging System Equipment, DC Charging Equipment for Electric Vehicles	Safety standards for DC charging equipment used in electric vehicle charging stations	Specifies transformer insulation tests and insulation design
P3105	IEEE Recommended Practice for Design and Integration of Solid-State Transformers in Electric Grid (Under Development)	Recommends best practices for MF or HF transformers used in SSTs	Recommendation for standardized test methods and procedures for SST based transformers

- IEC 61851-23 and UL 2202 are safety standards specify insulation designs and testing of magnetics for EVSE.
- P3105 aims to recommend Standardized testing and procedures for SST based transformers.



Application focused Standards Examples - DERs

Standard	Description	Key Focus	Relevance to Magnetics
IEEE 1662	IEEE Recommended Practice for the Design and Application of Power Electronics in Electrical Power Systems	Ensures efficient integration of power electronics in electrical power systems >100kW, <=52kV AC or DC	Specifies Isolation needs in DC/DC and PE grounding needs
IEEE 1547	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (Under Development)	Specifies the standards for the interconnection of distributed energy resources with power systems	Crucial for reactive power handling, limitation of current distortion – drives inductance spec for low pass filter
UL 1741	Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources	Safety standards for inverters, converters, and interconnection systems for distributed energy resources	Key for the design and safety of inverters and power converters in renewable energy systems – refers to UL 5085 and UL 506 for LV transformers

- IEEE 1547 drives the inductance spec in low pass filters.
- IEEE 1662 specified the PE system grounding and isolation needs.
- UL 1741 establishes product focused standards – UL 5085 and UL 506



LV Inductor Example - Product Focused Standards

Standard	Description	Magnetics Focus	Relevance to Power Electronics Applications
UL 1446	Systems of Insulating Materials – General	Test procedures to assign Thermal Class rating for transformers and inductors	Affects insulation design ensuring safe operation in power electronics
UL 840	Insulation coordination including clearances and creepage distance for electrical equipment	Defines insulation coordination and required clearances for safe electrical design	Critical for designing safe and efficient power electronic systems and transformers
UL 5085 1-3	Standard for Low voltage transformers (USA <600 V and Canada 750 V)	General requirements, safety for low-voltage transformers in residential and industrial applications – conformity tests	Guides design and safety in low-voltage transformers
IEC 61558	Safety of Transformers, Reactors, and Power Supplies	Electrical safety requirements for transformers and power supplies	Critical for designing safe and efficient low-power transformers
IEC 61857 -1	Electrical Insulation Systems – Procedure for Thermal Evaluation	Procedures for evaluating insulation systems under thermal stress	Helps ensure transformer longevity and performance in high-power applications
IEC 60068	Environmental Testing	Defines testing procedures for durability under environmental stresses	Ensures transformers can withstand temperature, humidity, and vibration variations
IEEE 389	IEEE Recommended Practice for Testing Transformers and Inductors for Electronics Applications	Testing methods for determining significant parameters and including performance characteristics.	Test practices for qualifying inductors and transformers in specific application. P61007-389 – active PAR

