# High Speed Direct Drive Motors Enabled by SiC Power Devices

High-Megawatt (HMW) Direct-Drive Motor Workshop

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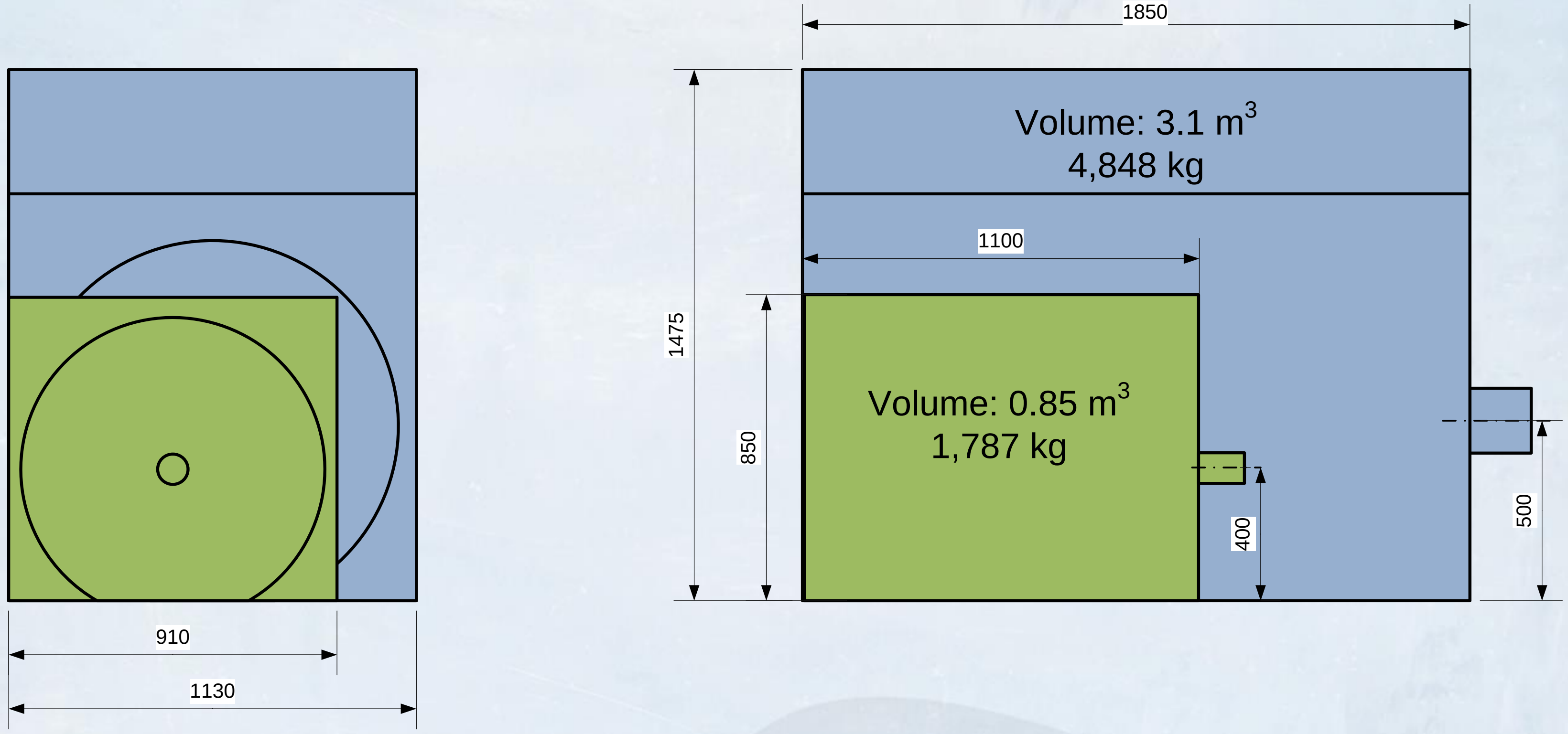
# High Speed v. Conventional Motor Comparison




2 MW 1,800 rpm v. 2 MW 22,500 rpm

# High Speed Motor Technology Design Considerations

- Rotor dynamic performance
  - Mode separation and margin across entire speed range
  - Supercritical rotor complicates bearing design and reliability
- Thermal management
  - High power density requires liquid cooling in the stator
  - Eddy current losses require use of Litz wire or Roebel coils in the stator winding
  - Core losses require use of thin laminations (0.18 mm or less)
  - Unconventional air circulation schemes to overcome pressure drop at air gap
  - Oil film bearings are lossy. Magnetic bearings are preferred
  - Power quality (or lack thereof) affects rotor heating
  - High efficiency is critical
- Stress management
  - Rotor containment
  - Magnetic bearing rotating components

# High Speed Motor Technology Design Considerations

- Torque pulsation
  - Large air gaps and good power quality reduce torque pulsation
- Motor insulation and coil design
  - Litz wire or Roebel coils to limit eddy current losses
  - Corona and grading tape use in medium voltage to reduce insulation stress and overheating
  - Lead design must consider skin effect
  - Thermal conductivity v. dielectric stress
  - End turn length
- Power quality
  - Drive and motor ideally designed in conjunction
  - Limitations on switching frequency in drives can produce low and high order harmonics
  - Magnet configuration in PM machines can affect power quality

# Variable Frequency Drives for High Speed Application

- High frequency drives are usually de-rated versions of commercial low frequency drives
  - Low switching frequency is not conducive to good power quality
- Compliance to IEEE 519 does not guarantee good motor performance
  - Current THD 2% or better to reduce rotor heating and prevent catastrophic rotor failure
- Interleaving can support high fundamental frequency without increasing switching frequency
- Low voltage cell design offers opportunities to improve power quality and efficiency – Drive segmentation
  - Use of SiC MOSFET
  - High switching frequency (>10 kHz)

# TWMC's VersaBridge

- Modular design can be used in low, medium and high voltage applications and wide range of power outputs

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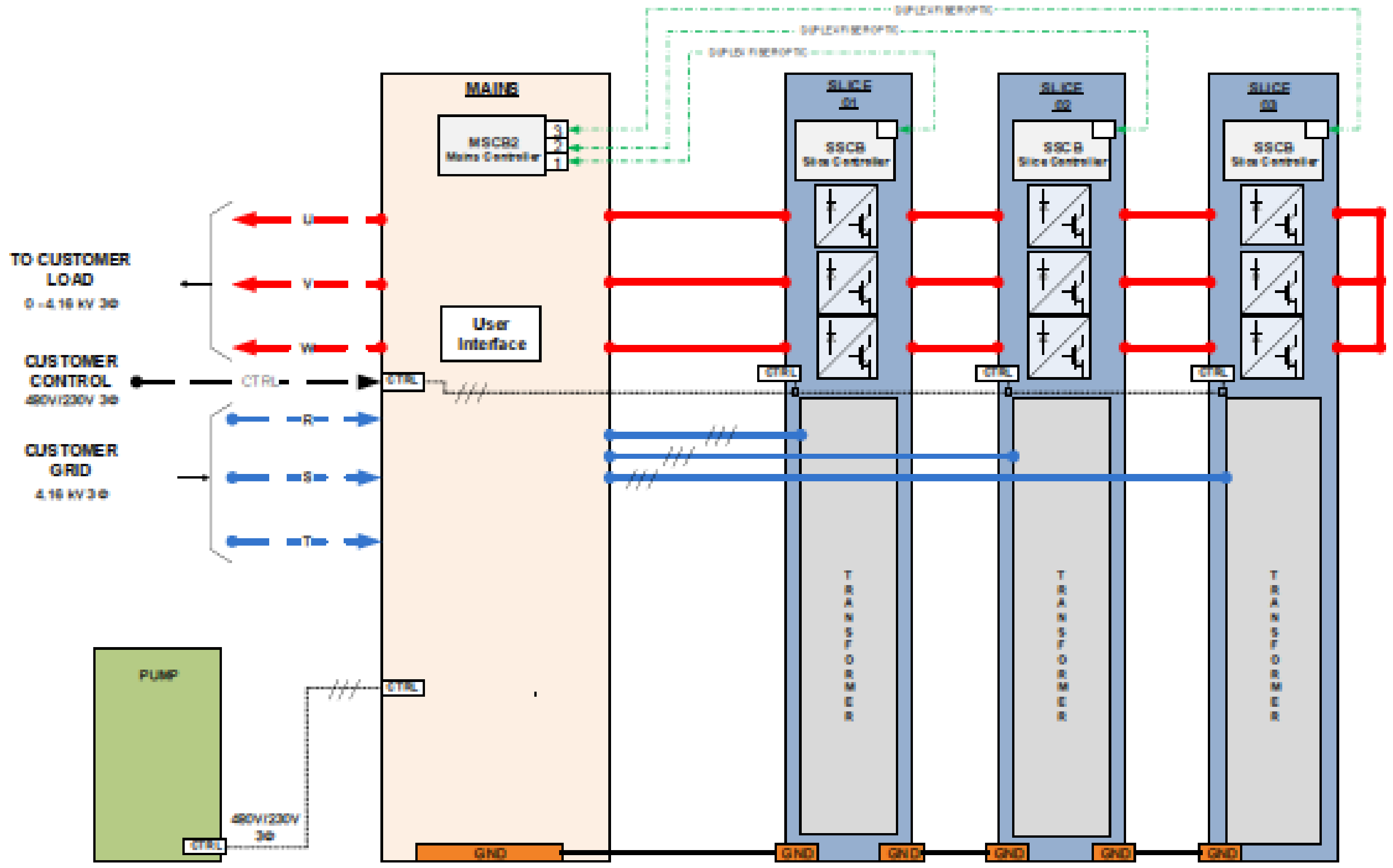
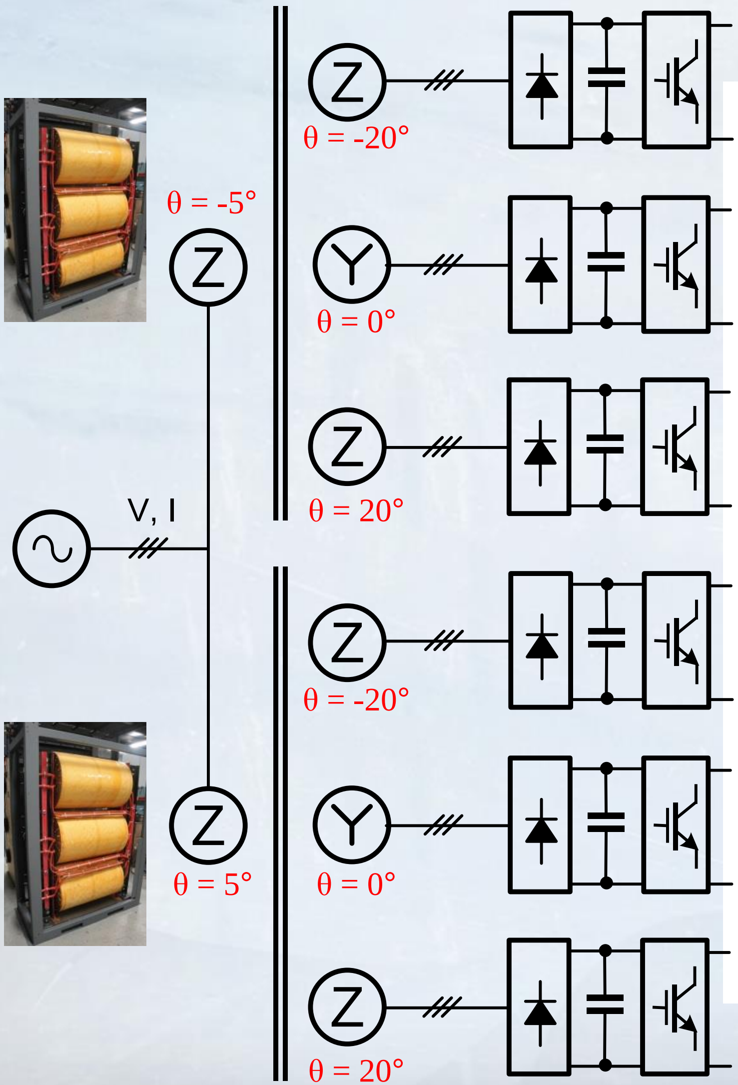
2,250 kW

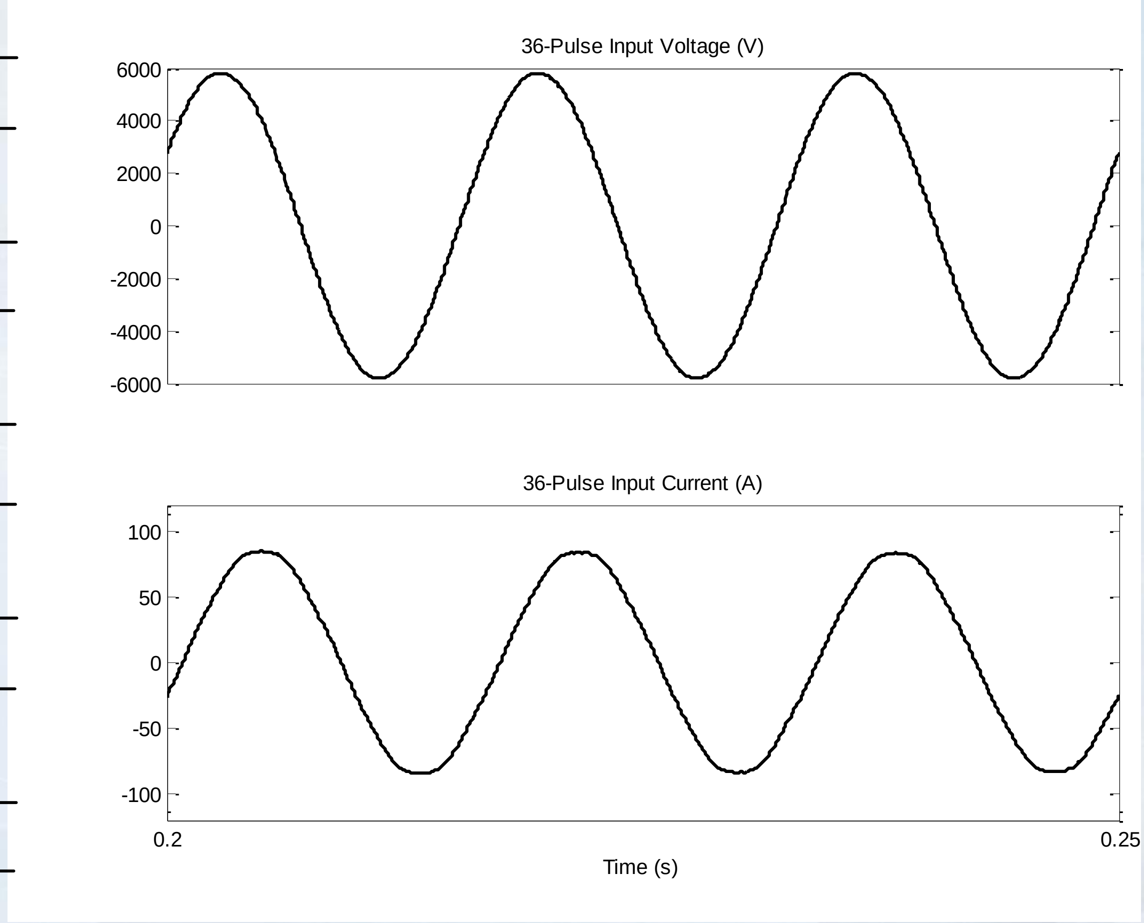
4,000 kW

# VersaBridge System Schematics



# 36-Pulse Rectifier with two 18-pulse Transformers



# TWMC VersaBridge Multi-Level Topology

- Unidirectional Power
  - 750 kW/Slice
  - Carrier Frequency
    - (2n+1) x Device SF
      - n = number of series cubes
      - Device SF = 0.3 to 6 kHz
    - 4.2 kHz to 6 kHz typical
    - 20 kHz or higher possible
  - Input
    - 18 pulse transformers
    - 18 + 18 pulse system
  - Induction Motor Control
    - V/Hz
    - Vector
  - Independent Liquid Cooled
    - Electronics
    - Transformer

- Bidirectional Power
  - 500 kW/Slice
  - Carrier Frequency
    - (2n+1) x Device SF
      - n = number of series cubes
      - Device SF = 0.3 to 6 kHz
    - 4.2 kHz to 6 kHz typical
    - 20 kHz or higher possible
    - 6 kHz input
  - Input
    - 6 kHz typical carrier
    - Electronic phase shift
    - More slices →lower grid THD
  - Induction Motor Control
    - V/Hz output only
    - Vector input & output
  - Independent Liquid Cooled
    - Electronics
    - Transformer

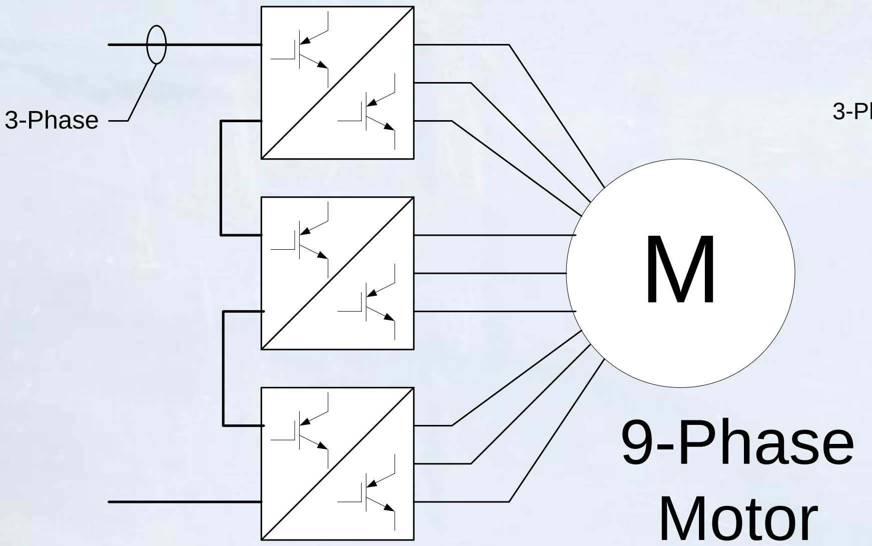
# TWMC VersaBridge Multi-Level Topology

- Existing
  - Semiconductor Solution:
    - IGBTs + Diodes (Si based)
  - Transformer Solution:
    - Iron core transformer
  - Slice
    - Power converter + Transformer
  - Liquid Cooling
  - Distributed Control
  - Series & Parallel Solutions

- Future Vision
  - Semiconductor Solution:
    - IGBT + SiC Diode
    - SiC Transistor +Diode
  - Transformer Solution
    - None – motor winding and VSD matched
    - High frequency core
  - Slice
    - Power converter (+ Transformer)
  - Advanced Liquid Cooling
  - Enhanced Distributed Control
  - Series & Parallel Solutions

# TWMC VersaBridge Transformerless Topology

## No Transformer




## High Frequency Isolation Transformer