CENTER FOR
POWER OPTIMIZATION OF ELECTRO-THERMAL SYSTEMS

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Converter-Integrated Variable-Pole Induction Machine Drive for Heavy-Duty Vehicles

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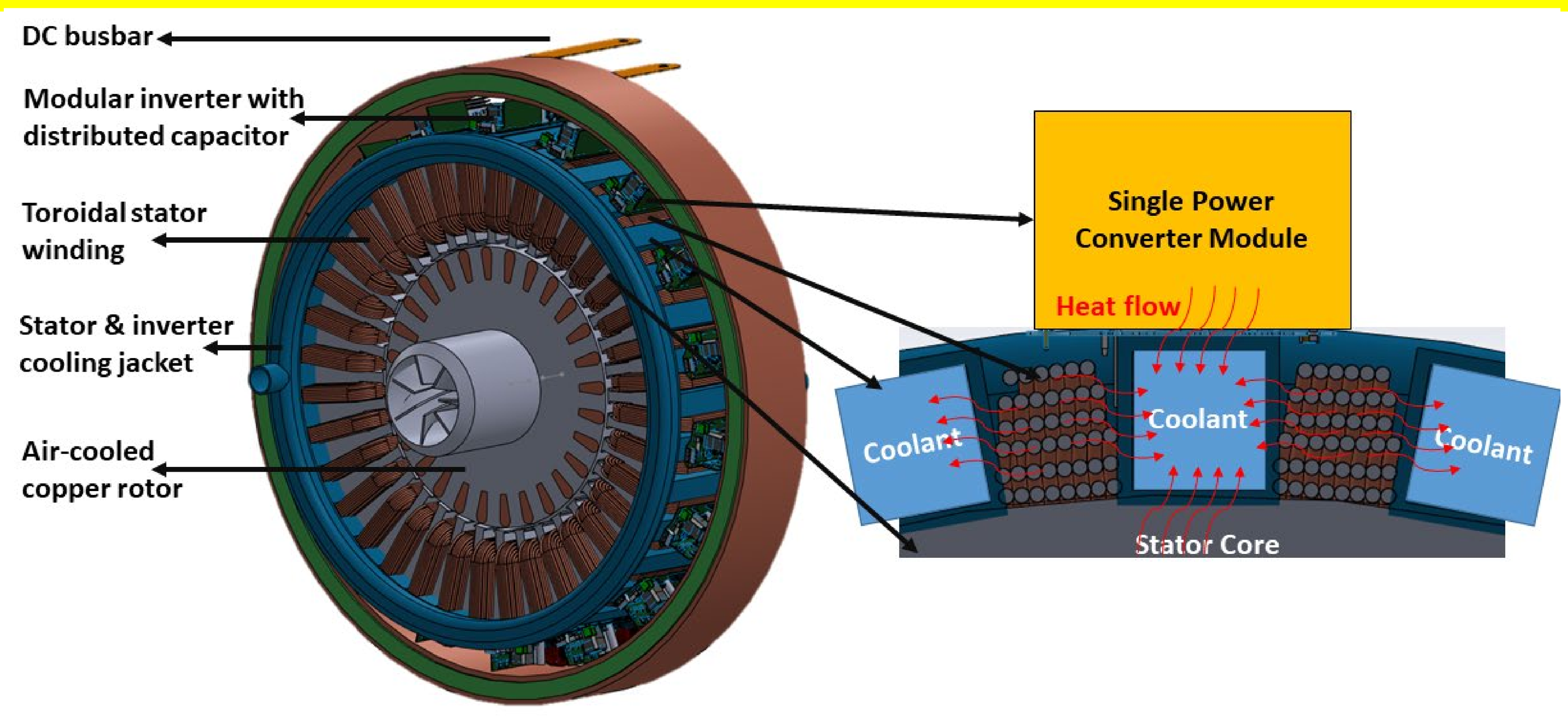


200 kW peak (30s), 800 V dc link, 20,000 RPM (max speed)
→ **Target:** 10X power density improvement

1) Electronically varying the induction machine magnetic pole count leads to **high drive cycle efficiency** and improved **torque speed envelop.**

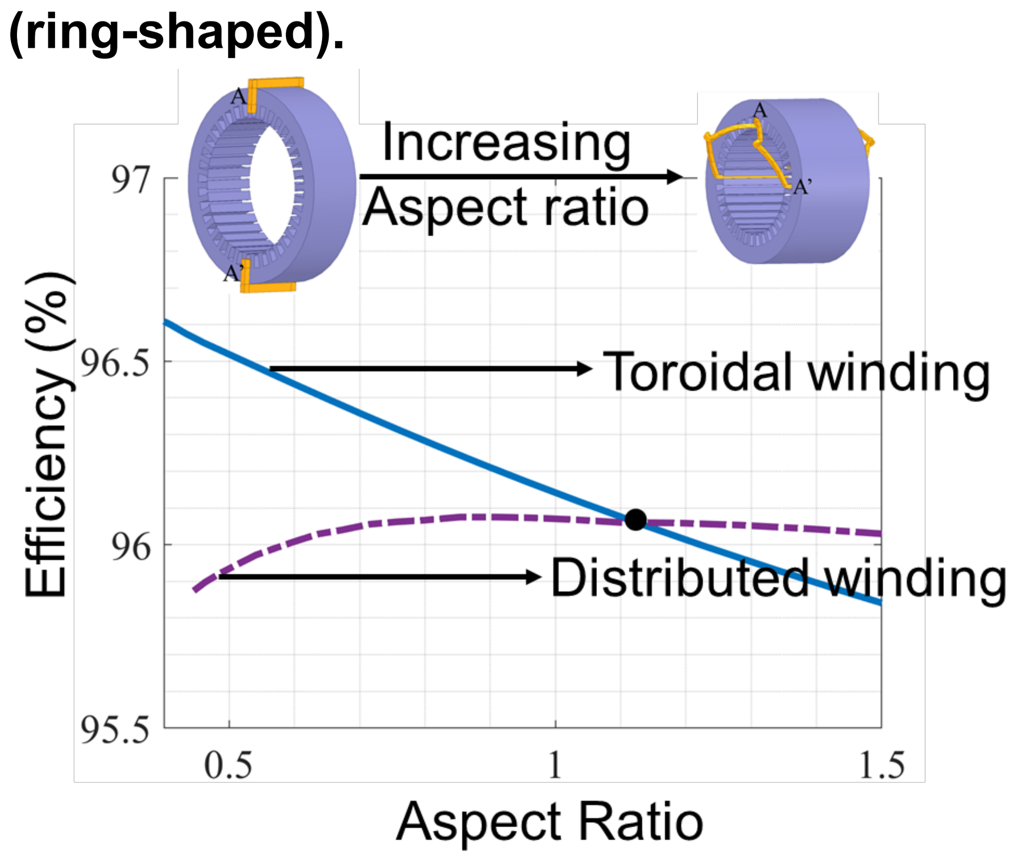
2) Toroidal winding + integrated 18-phase converter →**Low losses and better thermal management** leads to **higher power density**.

3) **Increased exposed winding surface area** compared to distrusted winding → Higher current density.

Integrated electromagnetic and thermal co-design of variable-pole induction motor and 18-leg converter to achieve 10X system-level power density improvement.

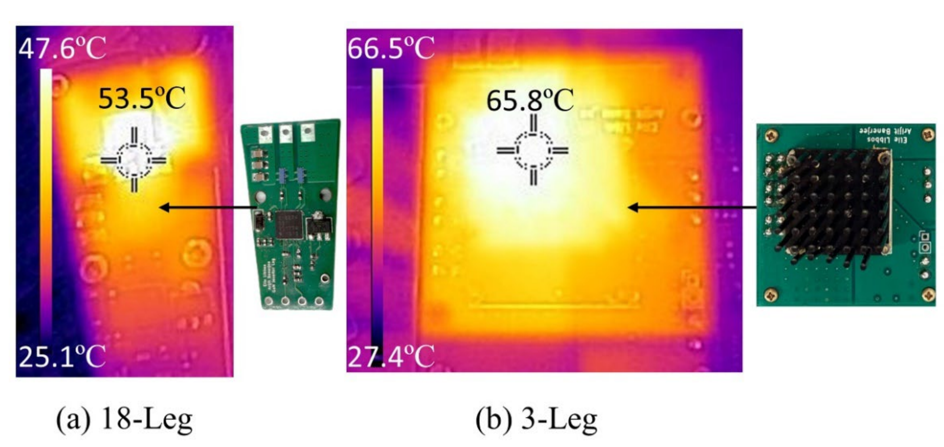
Key Results

(1) Toroidal windings achieve higher efficiency with lower aspect ratio (ring-shaped).

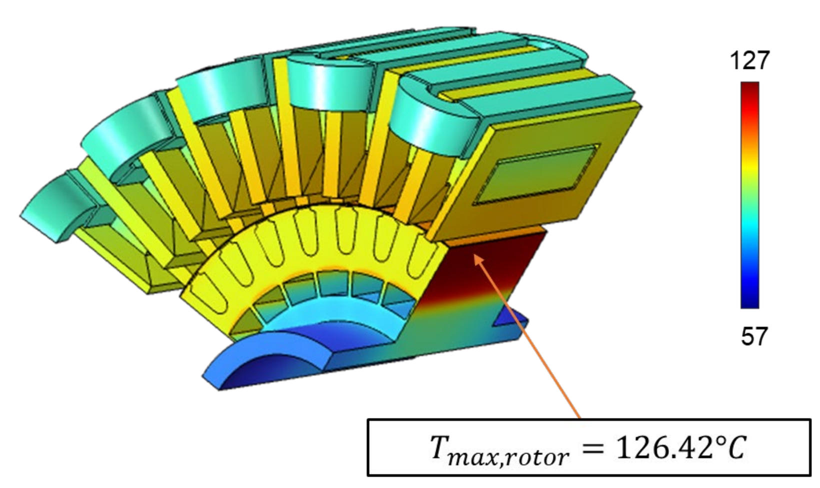


(2) High number of inverter legs

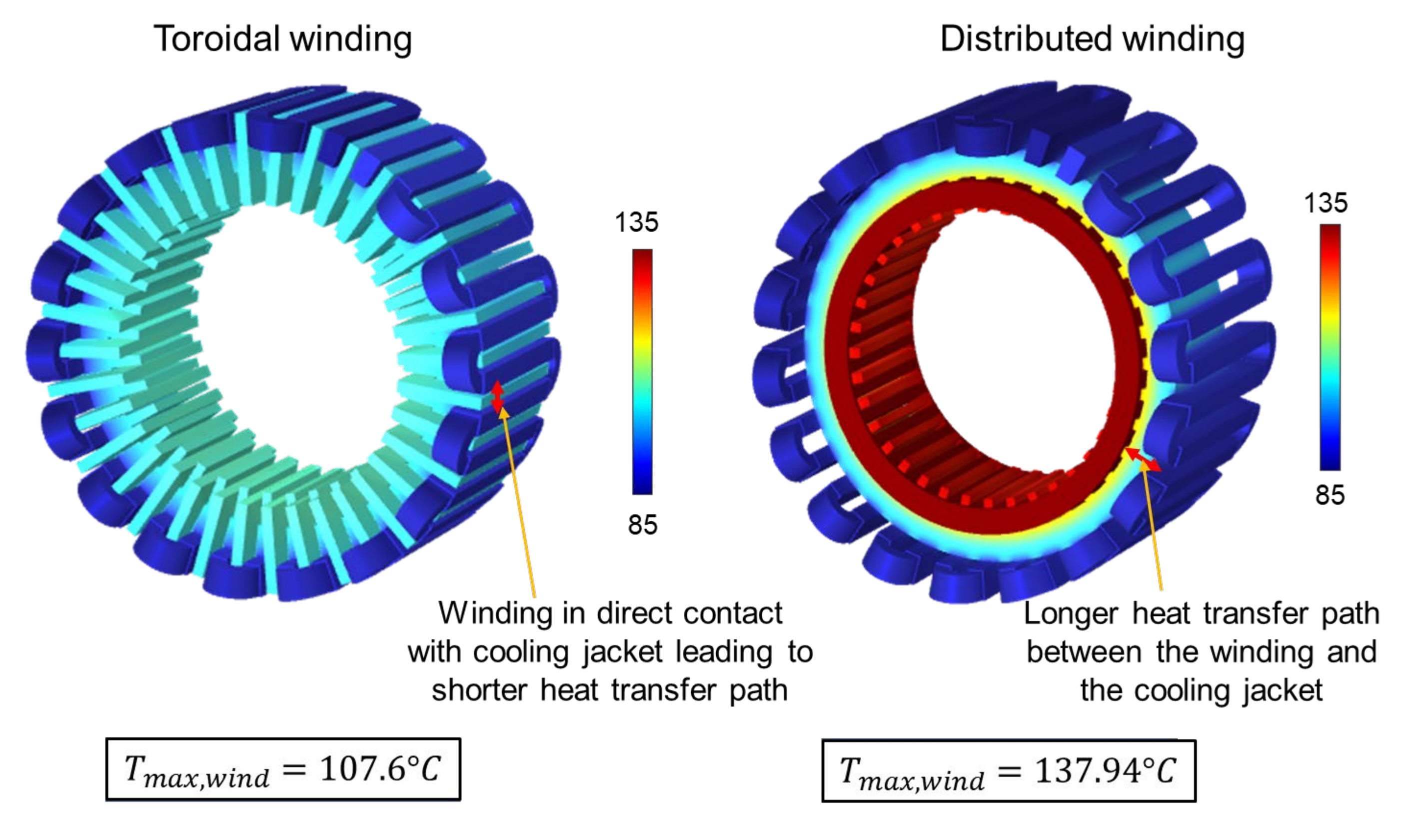
- **62 % less dc link capacitance.**
- **Lower switching loss.**
- **Better thermal performance.**



(a) 18-Leg (b) 3-Leg

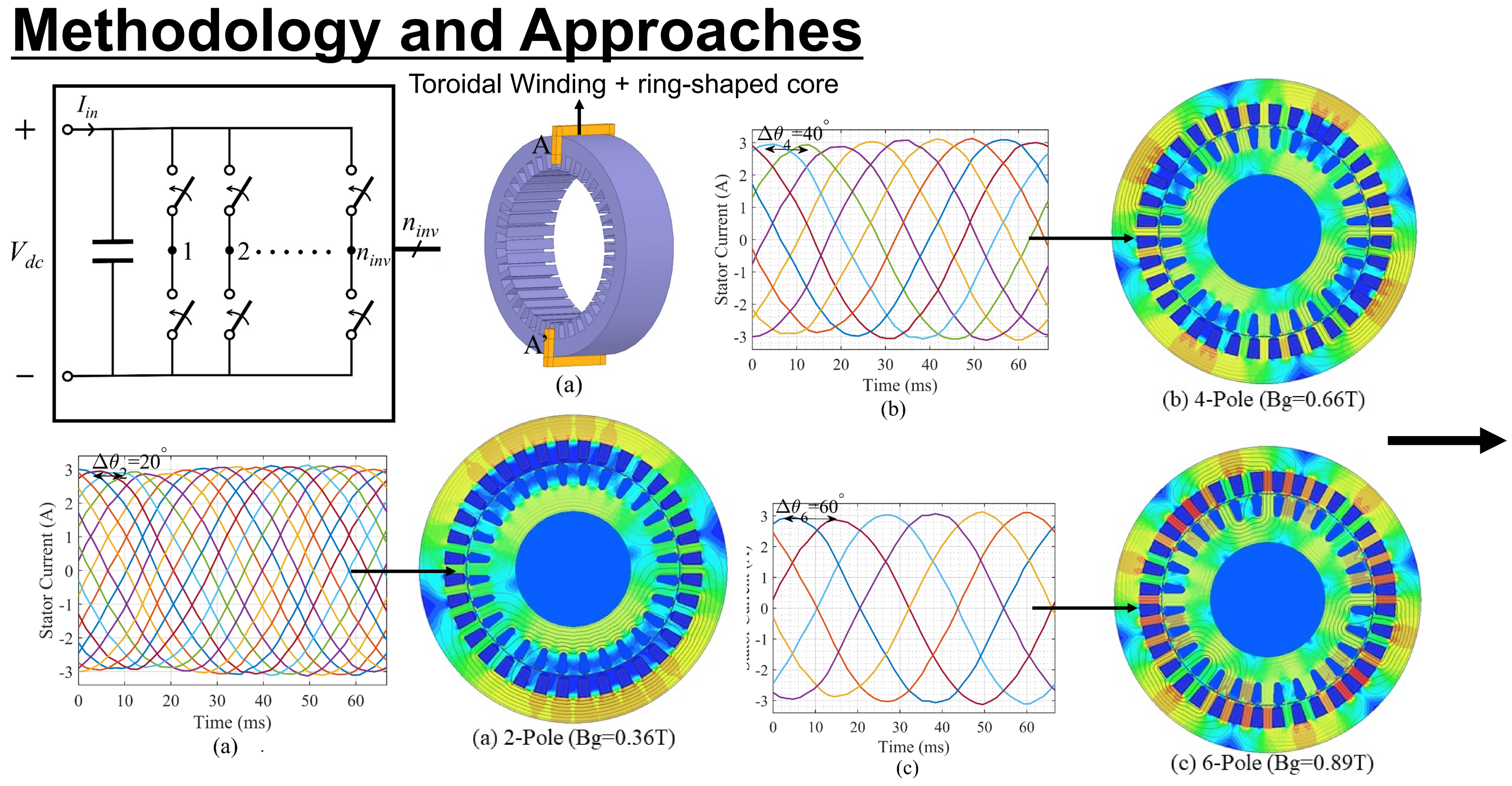


(3) Enhanced thermal performance for toroidal windings as compared to distributed windings

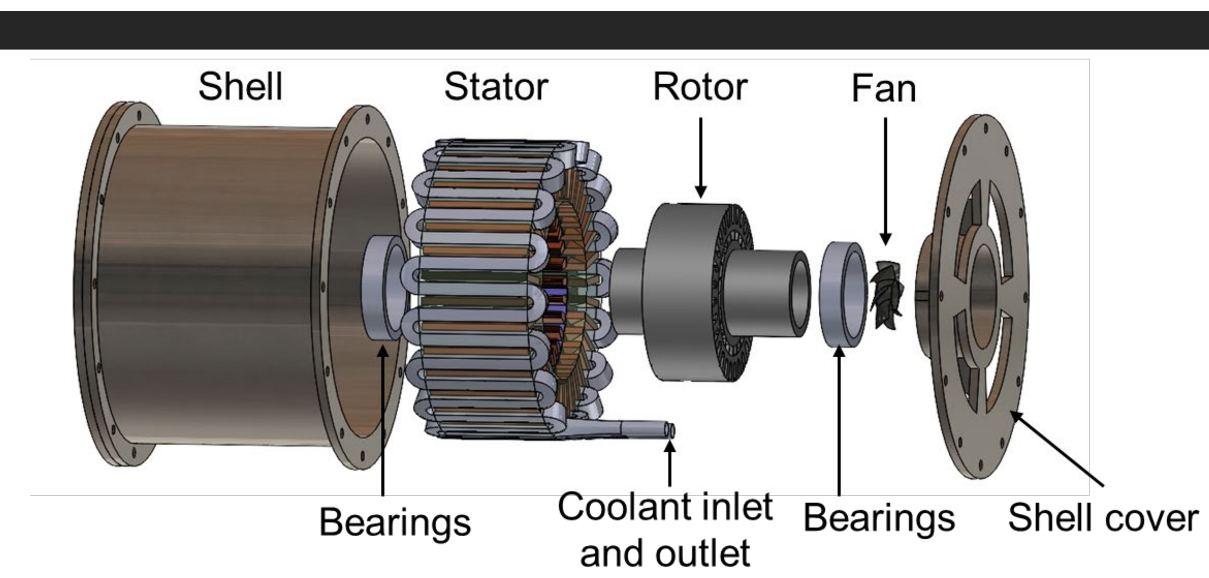


(4) Efficient cooling methodology to push power density to 40 kW/L

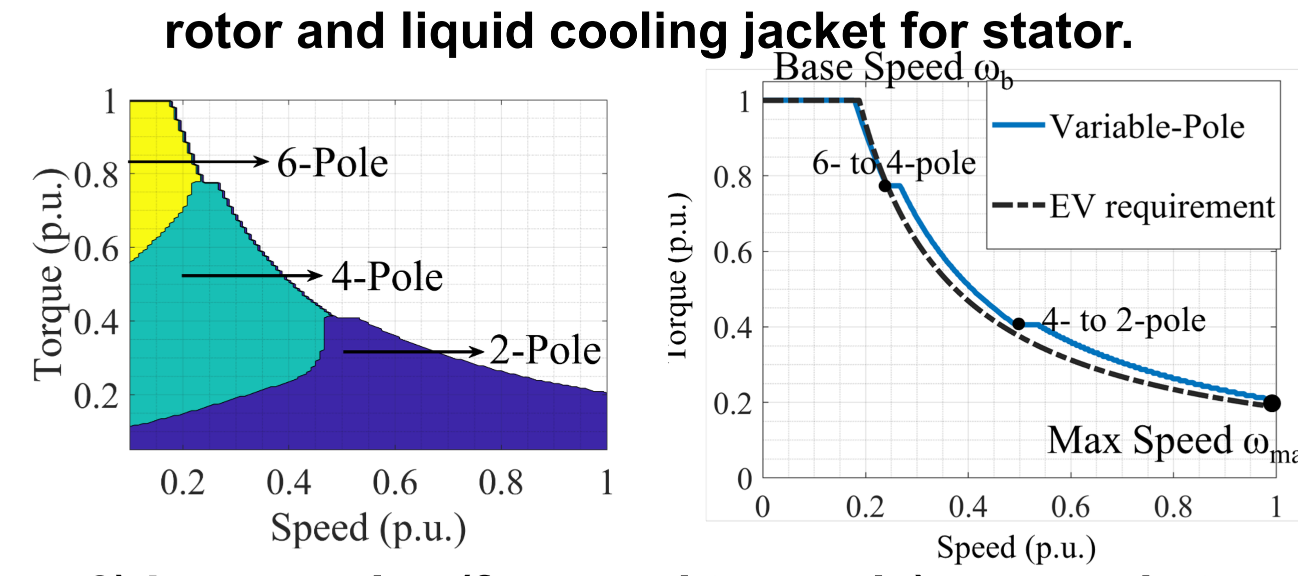
Methodology and Approaches



(1) High number of inverter legs (18-phase) and toroidally-wound induction motor → Electronic pole-changing.



2) Integrated cooling design → forced air cooling for rotor and liquid cooling jacket for stator.



3) Lower poles (four- and two-pole) are used at partial torque and high speed to improve drive cycle efficiency and torque speed envelop.

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