Holistic Life Cycle Cost Optimization of the Traction Inverter

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Key parameter indicators(KPI) and Design Chapters [1]

- Volume (50kW/L)
- Losses/Efficiency (99.5%)

Additionally, **life cycle cost optimization** (LCCA) is required to select the design that is both economically and energy-wise favorable.

- Cost
- Reliability

Specifications

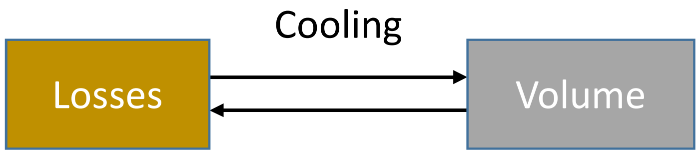
1. $P_{out} = 300\ kW$
2. $V_{in} = 1250\ V$
3. $I_{in} = \frac{P_{out}}{V_{in}} = 240\ A$
4. $\hat{V}_{l-n} = \frac{V_{in}}{2} = 625\ V$
5. $\hat{I}_l = P_{out}\ \hat{V}_{l-n} = 320\ A$

1. **Heat sink and cooling types**
   - Cold plate and liquid cooling
   - Air cooling and heat-sink design
2. **Selection of topology and power modules**
   - 2-level : Half-bridge modules
   - 3-level NPC, TTC : Half-bridge modules, common-collector modules
   - Segmented/multi module/phase structures
3. **Capacitor bank for DC-link**
   - Maximum voltage ripple
   - RMS current of the capacitor bank (thermal issues)
4. **Bus bar design**
   - Low inductance laminated connection
     - To decrease switching noise
     - To decrease switching losses
5. **Auxiliary circuits:**
   - Gate drives and sensors
   - Power supplies
6. **Connectors and Filters :**
   - Input, output ; common mode, differential mode

Loss and Volume Breakdowns \ Considered Topologies [2,3]

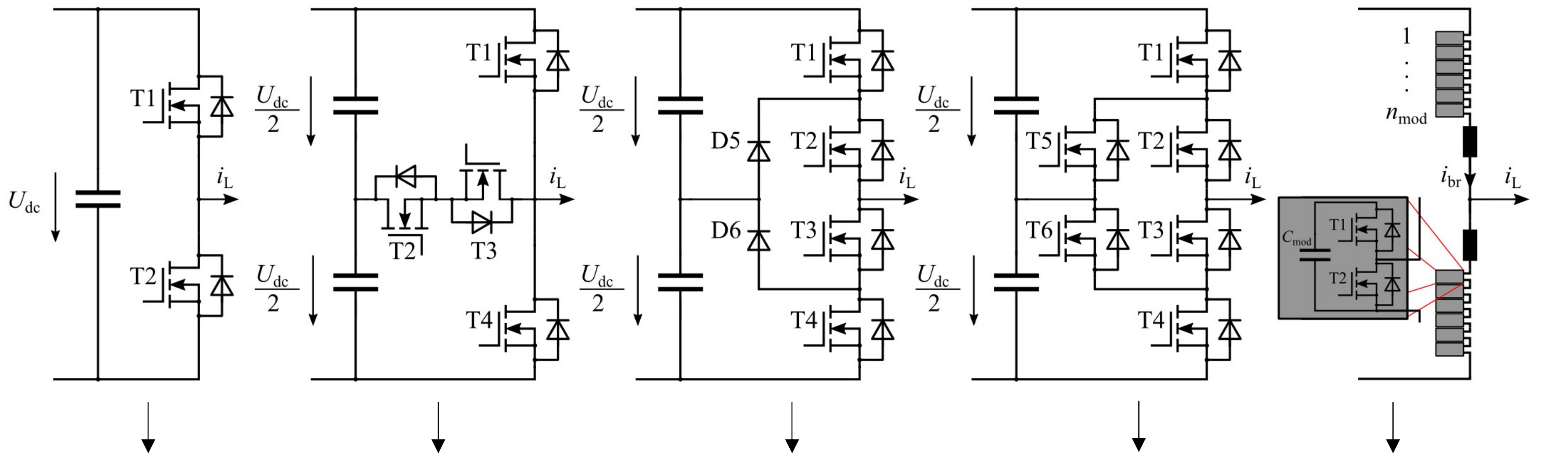
Losses

1. Power semiconductors (90 %) (eff 99.5%)
    - Conduction Losses
    - Switching Losses
    - ~~Driving losses~~
    - ~~Leakage Losses~~
2. Additional Losses (10%)
    - Filters losses



Volume

1. Power Module (12%)
2. Gate Drives (3%)
3. Capacitor (24 %)
4. Cooling (32 %)
    - Cold plate
    - Heatsink
5. Others (29%)



Two-level (2L) Inverter

Three-level T-Type (3L-TT) Inverter

Three-level Neutral Point Clamped (3L-NPC) Inverter

Three-level Active Neutral Point Clamped (3L-ANPC) Inverter

Modular multilevel converters (MMC)

Stepwise Design Methodology and Multi-objective Optimization [4,5]

Key performance indicators:

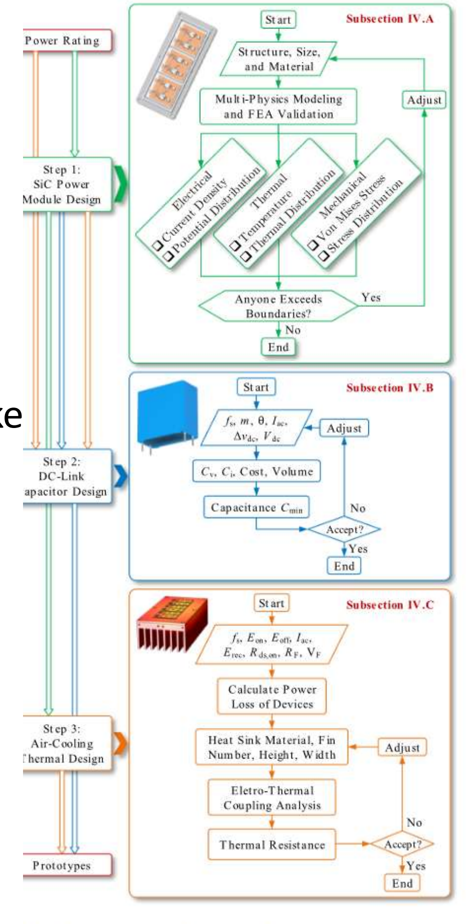
- Higher efficiency
- Smaller volume
- Higher reliability
- Lower cost
- Life cycle cost

Optimization :

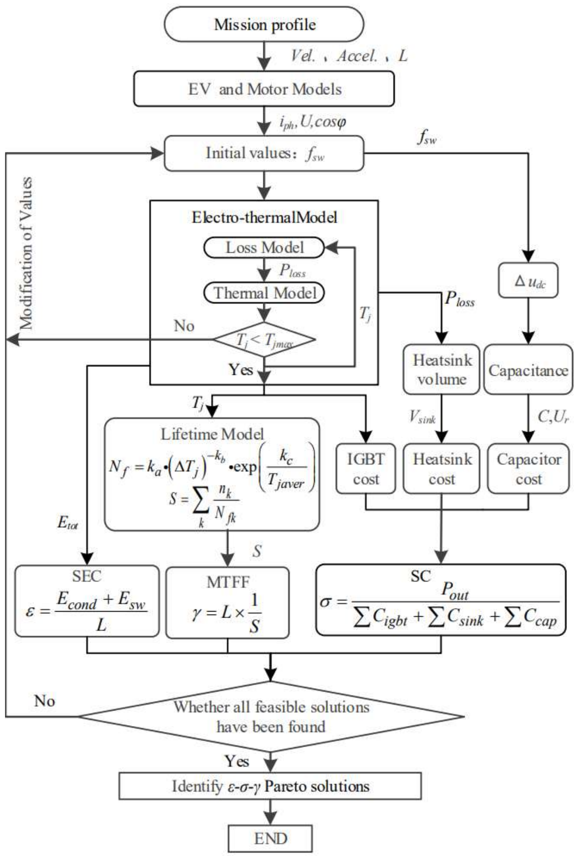
- Stochastic optimizations like Genetic Algorithm
- Direct search
- Pareto frontier

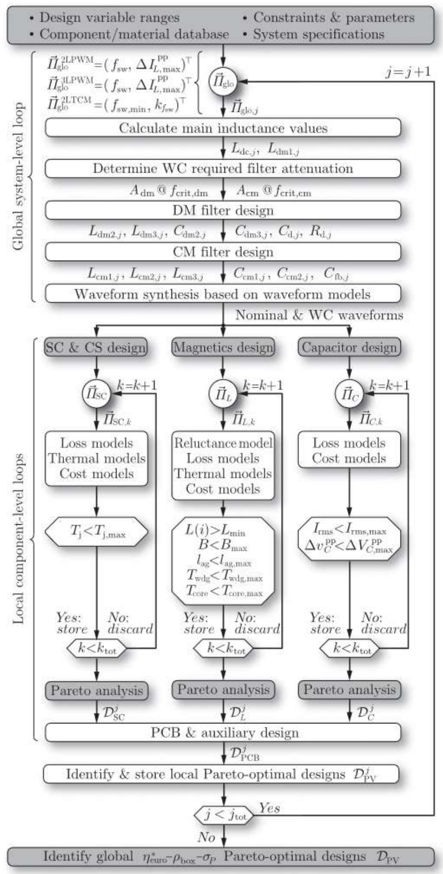
Inputs:

- Mission profiles
- Power ratings (Voltage, Current)



. 4. Stepwise design methodology of air-cooled inverter in power module, link capacitor, and heat sink levels.





References

- [1] A Compact 250 kW Silicon Carbide MOSFET based Three-Level Traction Inverter for Heavy Equipment Applications
- [2] Stepwise Design Methodology and Heterogeneous Integration Routine of Air-Cooled SiC Inverter for Electric Vehicle
- [3]Potentials and Comparison of Inverter Topologies for Future All-Electric Aircraft Propulsion
- [4] Multi-objective optimization design of electric vehicle converters based on ε-γ-σ
- [5] Comparative Life Cycle Cost Analysis of Si and SiC PV Converter Systems Based on Advanced η-ρ-σ Multiobjective Optimization Techniques