The gap between large power converters and small power converters

And how it is closing

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Mind the gap
Thermal management

- Surface area to volume ratio
  - 1 meter (3 foot) cube = 6
  - 0.1 meter (4 inch) cube = 60
  - 0.01 meter (1/2 inch) cube = 600
  - 3 meter by 3 meter cube = 2
  - 10 meter by 10 meter = 0.6

Surface area

\[ SA = 6l^2 \]

Volume

\[ V = l^3 \]

\[ \frac{SA}{V} = \frac{6}{l} \]
# Power loss effects

<table>
<thead>
<tr>
<th>Converter power</th>
<th>Losses at 85% efficiency</th>
<th>Losses at 95% efficiency</th>
<th>Losses at 98% efficiency</th>
<th>Losses at 99.5% efficiency</th>
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<td>2W</td>
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Losses kW vs Converter Power kW

- Losses at 85% efficiency
- Losses at 95% efficiency
- Losses at 98% efficiency
- Losses at 99.5% efficiency
Cooling
Historic loss expectations

- Small converter loss is approaching historic large converter loss
- Loss halves every ten years
Power Loss economics

- Lifetime power losses are more than the converter cost
- Total cost of ownership dominated by losses
Cost of efficiency

- 200W converter
- 90% efficient
- Power loss is 20W
- 24 hours a day
- 365 days per year

- Cost per year of the losses
- 175.2 kWh
- $0.10 per kWh
- $17.52 per year
- 3 year life
- $52.56
Power converters TCO

- Large converters
- Efficiency > 99%
- TCO dominated by losses
- Everybody knows
- Tender documents have maximum losses specified with financial penalties

- Small Converter
- Efficiency < 95%
- TCO dominated by losses?
- No one noticed?
- No one did anything?
Your efficiency power loss future

• Every 10 years the losses in all your converters will halve
• DoE curves show this
• Public policy drives this
• True across almost all energy consumption markets
• As losses drop control gets more difficult
Control Challenges
Control Challenges
Challenges

• No losses means low margin
• Low loss converters have more non linear behavior
The topology future

- More converters known by their filter name
  - LLC
  - LCL
  - LCLCL
- Cycloconverter
  - Minimize energy storage components
  - Storage energy at any frequency
Summary - control inspirations

- All system damping provided by control
- Most system damping is due to non-linearity
- Linearize control transfers
  - Frequency coupling models
- Grid variation is the true control challenge
- Grid interaction is the control problem
  - The filter is the plant!
  - The grid is the plant
  - Five bus equivalents
- Other converters
  - Sub Synchronous Resonance SSR analysis for converter interactions
- Control requirements from 0.0001Hz to 10kHz
Summary

• Small converters approaching losses of large converters
• Techniques for solving control issues are available
• Losses halve every ten years
• Mind the gap – it’s closing