Reliability of Grid-Connected Power Electronics: A Case Study (GR-14-03)
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Objectives

- To perform a case study on a commercial product to evaluate power electronics reliability.
- To identify the areas of reliability concern in the specific product and provide recommendations for improvement.
- To generalize the results and develop general guidelines and methodologies to study reliability of grid-connected power electronics systems.

Understanding Converter Topology

3-Phase Input
3-Phase Full-Wave Diode Rectifier
Intermediate Filter
Boost PFC
Boost Inverter
Internal DC Bus
Output 70-180 V
150-220 A

Insight into Converter Topology & Components

Three major Power Conversion Stages:

- Three-phase full-wave diode rectifier:
  - Boost PFC Converter:
    - Corrects power factor by drawing a current which is almost in-phase with the source voltage.
    - Improves PF up to 0.97.
    - Boosts the rectified DC voltage.
- DC/AC Stage:
  - Full-Bridge Inverter Operated at High Frequency.
  - Employs zero-voltage-switching strategy to reduce switching losses.
- AC/DC Stage:
  - Current Doubler Rectifiers for high output DC Current
  - Paralleled Converters to Supply the High Current Demand of the Electrolyzer

Identifying Reliability Concerns in the Electrolyzer Product by Proton On-Site

- Component Concerns
  - Resistive current sensing in PFC stage is vulnerable to noise.
  - Electrolytic capacitors and power switching devices such as IGBTs and MOSFETs are the most vulnerable components.
  - Electrolytic DC capacitor reliability
- Control Concerns
  - Current Sharing between two paralleled ZVS converter stages is not guaranteed.
  - Average current mode programming in the PFC stage does not provide cycle-by-cycle peak switch current limit.
- Thermal Concerns
  - During a Temperature cycle there is strain at all material interfaces. Over repetitive temperature cycles this strain can cause fatigue, cracks, joint degradation and eventual failure.
  - Power cycling failures on the MOSFET discretes. The stress is caused by differences in the linear expansion characteristics of the different materials.

Experimental Reliability Study

Two types of measurements will be performed:

- Measurements of external quantities
  - Dynamic output current response
  - Dynamic three-phase input current response
  - Steady-state and dynamic output current sharing among paralleled power supplies
- Measurements of internal quantities
  - Static and dynamic current sharing within the two paralleled DC-DC stages inside a power supply
  - Heatsink temperature
  - AC-DC stage MOSFET switching voltage waveform
  - DC-DC stage MOSFET switching voltage waveform
  - Boost power factor correction inductor current measurement
  - Output rectifier current measurement

Future Work

- Perform experimental study and measurements to evaluate single power supply performance.
- Experimental examination and evaluation of overall electrolyzer system operation in transient and steady state.
- Examine the ratings and stress levels of power semiconductor devices.
- Thermal analysis of the power converter components.
- Finalize power supply design review with recommendations for improvement.
- Generalization of the achieved results for grid-tied power electronic converters.