PROGETTO DOTTORATO DI RICERCA 2014:
Convertitori dc-dc ad elevata efficienza per l’ interfacciamento
di sorgenti di energia in sistemi di generazione distribuita

High Efficiency Interfacing DC-DC converters for distributed energy systems.

AGGIORNAMENTO DOPO IL PRIMO SEMESTRE

Giovedì 14 maggio 2015

Supervisore: prof. Giorgio Spiazzi
Dottorando: Davide Biadene
Considered Scenario

Renewable Energy Sources

Energy Storage

Grid Inverter

HV DC Bus

Interface DC/DC Converter

\[ V_{PV} \]

\[ V_{bus} \]

\[ V_{grid} \]

\[ V_{FC} \]

\[ V_{ES} \]
Interface Topologies for RES

- **Proposed Solution**
  - No Multiple Maximum Power Points;
  - Maximum Available Power from each RES;
  - High Voltage Gain DC/DC Converter;
  - Possible Galvanic Isolation.

- **Characteristics**
  - No Multiple Maximum Power Points;
  - Maximum Available Power from each RES;
  - High Voltage Gain DC/DC Converter;
  - Possible Galvanic Isolation.

**Unidirectional DC-DC Converters**
- Single Active Bridge (SAB)
- Interleaved Boost with Coupled Inductors (IBC I)
**IBCI Converter**

**Characteristics**
- Mutual Inductors;
- Output Voltage Multiplier;
- Resonant Tank;
- Galvanic Isolation.

**Advantages**
- Small Input Current Ripple;
- Less Switch Voltage Stress;
- Improved Voltage Gain;
- Controlled Switching Losses.

**Diagram**
- Mutual Inductors
- Voltage Doubler
- Resonant Tank
IBCI Converter

- IBCI Converter Characterization
  - Steady State Analysis (for almost all interested operating modes):
    - State Trajectories
    - Switch Voltage and Current Stress
    - Mode Boundaries
  - Voltage Gain:
    - Function of duty-cycle, frequency.
  - Output Power.
IBCI Converter

• Validation of the theoretical analysis
  • Simulation via Simulink-Matlab
  • Prototyping
  • State Trajectories Comparison
  • Voltage Gain Comparison
  • Efficiency Comparison
Optimum Design

- Design Choices
  - Switching Frequency;
  - Magnetic Core and Windings:
    - Winding Layout,
    - Core Type and Material.

- Design Objectives
  - Efficiency;
  - Volume;
  - Power Density;
  - ...

Background & Experience

Converter Model

Loss Model

Design Choices
Efficiency Optimization

- **Switching Losses**
  - Due to the stored energy in the switch parasitic capacitance;
  - $\propto$ Switching Frequency;
  - V-I superposition.

- **Magnetic Losses**
  - Magnetic cores and windings;
  - Different contributions:
    - Hysteresis Loss,
    - Classical Eddy Current Loss,
    - Excess Eddy Current Loss,
    - Relaxation Process.
  - Strongly Non Linear Behaviour;
  - Different detailed model approaches:
    - Steinmetz Equation (SE),
    - Generalized SE (GSE),
    - Improved GSE (iGSE),
    - Preisach Model.

Feasible Loss Model

- Magnetic Component and Winding Layout
- Switching Frequency
- Operating Mode
Conclusion

• **Addressed Issues**
  • Magnetic Materials:
    • comparison between different Loss Models proposed in literature,
    • Loss Measurement Methods.
  • IBCI Converter:
    • detailed steady-state analysis,
    • improved efficiency.

• **Future Issues**
  • Propose a Complete Design Procedure for DC/DC Converters,
  • Propose a feasible Magnetic Loss Model.