NEW CONFIGURATIONS OF POWER CONVERTERS FOR GRID INTERCONNECTION SYSTEMS

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Outline

• Chile in the World

• Introduction

• Micro-grids

• Power Converters in Micro-grids

• Power Converter topologies with MF/HF Isolation for Grid Interconnection Systems

• Conclusions
Chile in the World
Chile in the World

- Area: 756102.4 km²
- Population: 18,191,884 hbt.
- PIB: 24,170 USD

Hotel Metropol, Belgrade, Serbia
14-16 September 2016
Chile in the World
Chile in the World
Introduction
Introduction
The technological and economic development has lead to an increase in the energy demand.
It is well known that energy resources based on fossil fuels is very limited. Chile has little natural gas and oil resources. The extraction costs of coal are high.
There is a huge social opposition to the electrical development, because the perception of the community to this development is associated with environmental deterioration and social cost.
Introduction

Almost 4200 kms.
Introduction

- Limited fossil fuel resources.
- High extraction costs of fossil fuels.
- Social opposition for energy development.

This has lead to higher generation costs and thus high electricity prices for the consumers, affecting the competitiveness of the country.
Introduction

“A safe and efficient energy development, with reasonable prices, that take advantage of the renewable resources in a sustainable and non-polluting way”.
Introduction

Big earthquake 27 Feb. 2010 – 8.8° Richter
Big Storm 23-25 March 2015
Communication problems and thousands of people without electricity for several days
Introduction

Chilean energy program 2014-2018

Electrical Systems Interconnection
Introduction

Chilean energy program 2014-2018

Using non-conventional renewable energies
Introduction

Chilean energy program 2014-2018

Installations of micro-grids in isolated areas
Introduction

**Electrical Systems Interconnection**

- **Norte Grande Interconnected System**
  - Arica y Parinacota, Tarapacá, Antofagasta
  - 4,183,86 MW (20.6%)

- **Central Interconnected System**
  - Atacama, Coquimbo, Valparaíso
  - Región Metropolitana
  - Lib. B. O’Higgins, Maule, Bío Bío
  - Araucanía, Los Ríos, Los Lagos
  - 16,011,46 MW (78.7%)

- **Aysén System**
  - Aysén
  - 50 MW (0.3%)

- **Magallanes System**
  - Magallanes
  - 101,68 MW (0.5%)
Introduction

Amanecer 100 MW, the biggest in Latin America

Canela 78 MW

Colbún Machicura 3848 MW

Solar
724 MW
100.000 MW

Wind
911 MW
40.000 MW

Hidro
6,544 MW
21.000 MW

Geothermal
0 MW
16.000 MW

Biomass
442 MW
14.000 MW
Introduction

Huatacondo, the first microgrid in Chile

- 150 kW diesel generator
- 22 kW tracking solar PV system
- 3 kW wind turbine
- 170 kWh battery
- An energy management system

To improve the life quality of the population
Micro-grids
A micro-grid is a localized station with its own power resources, generation and loads.
Micro-grids involve multiple energy sources as a way of incorporating renewable energy, reducing costs and enhancing reliability.
Micro-grid system based on Solar/Thermal generation
Micro-grid system based on Wind generation

Micro-grids involve multiple energy sources as a way of incorporating renewable energy, reducing costs and enhancing reliability.
Micro-grid system based on Wave/Ocean generation
In this micro-hydropower system, water is diverter into the penstock. Some generators can be placed directly into the stream.
Micro-grids working in Islanded / Grid Connected mode
Power Converters in Micro-grids
Role of Power Converters

Power converters allow the integration to the electrical network of different kind of generation and distributions systems.
Power Converters used in Micro-Grid Applications

Two level Voltage Source Inverter

Three level Neutral Point Clamped Inverter
Power Converters used in Micro-Grid Applications

Cascade H-bridge

Modular Multilevel Converter
Power Converters used in Micro-Grid Applications

Most of power converters include storage elements

Two level Voltage Source Inverter

Three level Neutral Point Clamped Inverter
Power Converters used in Micro-Grid Applications

- **Cascade H-bridge**
- **Modular Multilevel Converter**

- Size
- Weight
- Failure Possibilities
Power Converters used in Micro-Grid Applications

- Simple and compact circuit.
- Directly connects the AC-source with any arbitrary AC-load.
- No need for storage elements.
- Suitable for applications where weight and size are important issues.
- Regenerative capacity.

Matrix Converter
Power Converters used in Micro-Grid Applications

AC7 - Matrix Converter

- A complete line of standard units for up to several megawatts and medium voltage using cascade connection.

- These units have rated power (voltages) of 9–114 kVA (200 and 400 V) for low-voltage MC and 200–6.000 kVA (3.3 and 6.6 kV) for medium voltage.
Power Converters used in Micro-Grid Applications

- Military
- Aerospace
- Wind Generation Systems

- No deeply studied in applications for grid interconnection of micro-grids, generation systems and/or loads.

Matrix Converter
A modified matrix converter topology for grid integration of two AC sources to the utility grid.

Power Converters used in Micro-Grid Applications

- New multilevel topologies have appear in order to use the matrix converter in high power applications.

- A multimodular matrix converter for wind power generation applications. (Each cell is an H-bridge)

Power Converters used in Micro-Grid Applications

- The structure allows the use of low voltage power semiconductors

Power Converter Topologies with MF/HF Isolation for Grid Interconnection Systems
Universal and flexible model for grid interconnection

Why? ... Chilean architecture network in only one direction
Universal and flexible model for grid interconnection

Providing a more flexible and modular power electronics interface able to connect different kind of sources and loads including medium voltage electrical networks, renewable energy sources and energy storage systems.
Universal and flexible model for grid interconnection

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Universal and flexible model for grid interconnection

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General structure of the universal and flexible model for grid interconnection

It requires a flexible power management control in order to ensure proper and secure operation of the networks.
Universal and flexible model for grid interconnection

The structure will allow the interconnection of different generation systems and loads with a multidirectional power flow capability.
Requirements for the future electricity network

- Galvanic Isolation
- Multi-directional power flow capability
- Flexibility and scalability
- Easy maintenance and low cost
- Compact power conversion and low weight
- High efficiency and reliability
MF/HF isolated AC/DC conversion solutions

Power converter configurations

AC/DC/MF/DC/AC
MF/HF isolated AC/DC conversion solutions

Power converter configurations

AC/DC/MF/DC/AC
MF/HF isolated AC/DC conversion solutions

AC/DC/MF/AC
Another MF/HF isolated AC/AC conversion solutions

Power converter configurations

AC/MF/AC
MF/HF isolated conversion solutions

Power converter configurations

- All the configurations are modular structures, allowing easy replacement of the cells in case of failure.

- All the configurations have the same number of commutation devices.

- All the configurations schemes are able to operate with multi-directional power flow.

- The third alternative does not include energy storage elements, reducing the weight and size. In addition, there is not need for DC-link controllers and the potential for failure is reduced.
### Universal and flexible model for grid interconnection

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Type of Isolated Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC/DC/DC/AC (VSIBM)</td>
</tr>
<tr>
<td>Number of stages</td>
<td>3</td>
</tr>
<tr>
<td>Number of DC link</td>
<td>2</td>
</tr>
<tr>
<td>Converter cell size</td>
<td>Bigger than the other two</td>
</tr>
<tr>
<td>Modulation</td>
<td>- Higher degree of ease</td>
</tr>
<tr>
<td></td>
<td>- Easier than CBM &amp; Dual-CBM</td>
</tr>
<tr>
<td>Commutation</td>
<td>- Easiest (Dead Time Method)</td>
</tr>
<tr>
<td>Conduction losses</td>
<td>- Lower than CBM &amp; Dual-CBM</td>
</tr>
<tr>
<td>Weight of Converter Cell</td>
<td>- Higher than CBM &amp; Dual-CBM</td>
</tr>
<tr>
<td>Literature</td>
<td>(Siemaszko, Zurkinden et al. 2009)</td>
</tr>
<tr>
<td>Core losses</td>
<td>3.9 W/kg</td>
</tr>
<tr>
<td>Ohmic losses</td>
<td>6 W/kg</td>
</tr>
<tr>
<td>Transformer Parameters</td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td>61.3 kVA</td>
</tr>
<tr>
<td>Weight</td>
<td>21.5 kg</td>
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<tr>
<td>Core</td>
<td>21.5 kg</td>
</tr>
<tr>
<td>Copper</td>
<td>11 kg</td>
</tr>
<tr>
<td>Frequency</td>
<td>2 KHz</td>
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<tr>
<td>Number of cores</td>
<td>1</td>
</tr>
<tr>
<td>Overall Efficiency</td>
<td>95.5 %</td>
</tr>
<tr>
<td>Overall Transformer Efficiency</td>
<td>94.7%</td>
</tr>
</tbody>
</table>
Modulation of AC/MF/AC i.e. Dual-CBM configuration

![Diagram of Dual-CBM configuration](image)

- **Input Cycloconverter Based Module (ICBM)**
- **Output Cycloconverter Based Module (OCBM)**

Symbols:
- $V_i$: Input Voltage
- $V_T$: Transformer Voltage
- $V_o$: Output Voltage

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Modulation of AC/MF/AC i.e. Dual-CBM configuration

When demanded frequency is equal to input frequency i.e. $f_i = f_o$
Modulation of AC/MF/AC i.e. Dual-CBM configuration

A case when demanded frequency is lesser than input frequency e.g. connecting 60Hz and 50Hz grids i.e. $f_o < f_i$

- Low order Harmonics – Worst filtering requirements e.g. large & expensive filters.
- Bad Spectrum – Difficult to eliminate low order harmonics.
Modulation of AC/MF/AC i.e. Dual-CBM configuration

Drawbacks of AC/MF/AC Single-Phase Converter (Dual-CBM)

- It is not a viable solution for the applications requiring frequency regulation e.g. v/f control of drives.
- Its failure in the applications interconnecting two systems at different frequencies e.g. interconnection of 60Hz and 50Hz grid.

Reason of Drawbacks
- Converter has single phase input i.e. output is limited to single phase input (in terms of selection).
Modulation of AC/MF/AC i.e. Dual-CBM configuration

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Possible Solution
- Increasing the input options of the converter i.e. utilizing the concept of matrix converters.
Evolution of a new AC/MF/AC topology

**Modifications in the topology**

- Utilizing 3-phase input. At any instant, three input options.
- Modularity, galvanic isolation, bi-directional power capability, etc.

A new 3-phase to 1-phase isolated AC/AC topology using three Dual CBMs
Evolution of a new AC/MF/AC topology

Input voltage ICBM

Input current ICBM

Input voltage OCBM

Input current OCBM

Input voltage OCBM

Input current OCBM

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Evolution of a new AC/MF/AC topology

Input frequency $f_i = 50$Hz

Output frequency regulation at 40Hz regardless of the input frequency change, i.e. 50-86 Hz, applied at time = 1s

Output frequency $f_o = 40$Hz
Extension to 3-phase to 3-phase isolated AC/AC topology

A new 3-phase to 3-phase isolated AC/AC topology
Conclusions
Conclusions

• The growing technological development has increased the demand of more available energy.
• It is necessary a safe and efficient energy development, with reasonable prices, that take advantage of the renewable resources in a sustainable and non-polluting way.
• There are several power converter topologies for micro-grid applications.
• Potential of isolated AC/AC direct converter topologies has been discussed.
• Identification of problem in a single cell i.e. in a single phase to single phase topology.
• Modification of the topology comes at the cost of an increased number of switching devices while keeping modularity intact as well as bi-directional power flow.
• This new AC/AC isolated topology will have a wider range of applications e.g. grid applications, AC drives etc.
IMPORTANT DATES
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Digest submission

July 31, 2017
Notification of acceptance

August 30, 2017
Final paper submission
Thanks for your attention ...

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