Microgrid & Supporting Technologies

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May 6, 2014
Outline

• Microgrid Layers
• Enabling Technologies at ESPEL
  • Power Electronic Converters
  • A New Inverter Topology
  • A New Wind Power Transfer System
  • Hybrid Wind-Solar and Storage Microgrids
• Outcomes
Microgrid Enabling

What is a microgrid

• ESPEL is involved:
  • Power Electronics
    • Circuit and Controls
  • Distributed Generation
    • Wind
    • Solar
    • Hybrid
  • Control and Supervisory Layer
    • Component and System
  • Energy Storage
    • Electrical
    • Mechanical

Power Electronics
-DC Choppers
Power Electronics
- AC-DC Rectifiers

Thyristor Based

Transistor Based
Power Electronics
- Inverter

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Enabling Technologies
- New Inverter Design

Diagram showing a new inverter design with components labeled as Pulse Generator, C1, L1, C2, L2, and Load. The diagram includes waveform displays showing the output voltage levels of 4.547 and 1.863 volts.
Inverter

High Frequency 2-20 kHz

Low Frequency 60 Hz

Infinite-Level Voltage
Simulation Results

1-Phase Pure Sinusoidal Voltage Tracking Performance, 110V, 60 Hz

Output Voltage
Reference Voltage

3-Phase Pure Sinusoidal Voltage Tracking Performance, 110V, 60 Hz

Phase a
Phase b
Phase c
Simulation of Robustness

**Input Voltage Change at t=0.05 sec, from 75 to 100V**

- **Output Voltage**
- **Reference Output**

**Arbitrary Voltage Tracking Profile, Single Switch Inverter**

- **Output Voltage**
- **Reference Voltage**
Load Change

Inductive Load Voltage and Current

Load (Ω)

<table>
<thead>
<tr>
<th>Load(Ω)</th>
<th>3+j1.88</th>
<th>6+j1.88</th>
<th>6+j3.77</th>
<th>6+j7.54</th>
<th>10+j3.77</th>
<th>20+j3.77</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD</td>
<td>0.09</td>
<td>0.10</td>
<td>0.09</td>
<td>0.10</td>
<td>0.15</td>
<td>0.23</td>
</tr>
</tbody>
</table>

\[ Z_L = 6+j7.54 \]
\[ Z_L = 3+j3.77 \]
Bipolar DC and HVDC

Robot Speed and Moving Direction Control

![Graph showing robot speed and moving direction control]

Output Voltage Reference

HVDC-Power Inversion, 400kV DC to 400kV AC 60Hz

![Graph showing HVDC power inversion]

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Variable Frequency

Variable Frequency (0-200Hz)

Amplitude (V) and (A)

Output Ref. Load Volt Load Current

Z_L = 3 + j1.88
New Inverter Experiment
Enabling Technologies
- Distributed Generation Wind Power
Hydraulic Wind Power
Nonlinear Modeling
-System Response

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Nonlinear Modeling
- State Space Simulation Results

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- Primary Motor Flow
- Primary Motor Angular Velocity
- Auxiliary Motor Angular Velocity
- Pump/Motor Gauge Pressure
Piecewise Affine Models
- Modeling and Control Approach

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Piecewise Affine Models
-Experimental Validation
Control and Supervisory Layer

• Control of Power Converters
  • Explore the functionality and control of
    • Rectifiers
    • Inverters
    • Choppers

• Control of Distributed Generation
  • MPPT
  • Power Tracking
Enabling Technologies
- Distributed Power Generation

• Hybrid Wind-Solar-Battery

![Diagram of Hybrid Wind-Solar-Battery System]

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Control of Wind Unit
Control Performance

The characteristic curve of wind turbine

Torque-Rotor Speed Characteristics of Wind Turbine

Wind MPPT Tracking Profile

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Control of Solar Unit
Control of Combined Wind-Solar System

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Outcome

- 37 Patent Disclosures/Applications
- 90 Paper Publications
- 2 Startup Companies
  - Hydraulic Wind Power LLC
  - Single Switch Systems Inc.
- 5 MS students
- 1 PhD student
- ~15 Undergraduate students
Conclusion

• Research Focus
  • Energy
  • Power Converters
  • Controls
  • Microgrids
  • Storage

• Manufacturing Capability

• Research and Validation

• Commercialization (on the way)
Thank you.

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