The IEEE First International Conference on DC Microgrids

http://www.icdcm.co/

June 7-10, 2015
Sheraton Atlanta Hotel
Atlanta, Georgia, USA
Organizers

• Krishna Shenai, Ph.D., General Chair, LoPel Corporation
• Rajendra Singh, Ph.D., Technical Chair, Clemson University
• Bernd Wunder, Fraunhofer Institute
• Keith Corzine, Clemson University
• David E. Geary, Universal Electric Corp.
• Herbert L. Ginn, Univ. of South Carolina
• Roger Dougal, Univ. of South Carolina
• Sol Haroon, IP UtiliNET
• Maryam Saeedifard, Georgia Inst. of Tech.
Subject Areas

• DC Microgrids
  – Developing Areas,
  – Data Centers,
  – Telecom Sites,
  – Smart Homes
  – Buildings
• AC/DC Hybrid Systems Implementations
• DC Microgrid Performance Studies / Analysis / Simulations and Business Models
• Cyber Security
• DC Devices, Protection and Switching
• Batteries / Storages
Plenary Speakers

• Dr. Keiichi Hirose, NTT Facilities, Inc. Japan
  Evolution of DC Microgrid from Telecom/Data-Center Infrastructure- 10-Year Experience and Next Challenge

• Dr. Mario Tokoro, Sony Computer Science Laboratories, Inc., Japan
  DC-Based Open Energy System – A Sustainable, Dependable, and Affordable Solution for Next-Generation Electrical Power Infrastructures
Keynote Speakers

• Dr. Mohammad Shahidehpour, Illinois Institute of Technology,
  *DC Microgrids in Smart Cities: Economic Operation and Enhancement of Resilience by Hierarchical Control*

• Dr. Kumar Venayagamoorthy, Clemson University,
  *Situational Intelligence and Intelligent Control of DC Power Systems*

• Dr. Josep M. Guerrero, Aalborg University, Denmark
  *Advanced Control Architectures of DC Microgrids*

• Dr. Scott Backhaus, Los Alamos National Laboratory,
  *Summary of DOE DC Microgrid Scoping Study Draft – Opportunities and Challenges*

• Mr. Robert F. Lachenmayer Jr., Schneider Electric, USA
  *Implementing and Enabling Business Model for DC Microgrids*
Keynote Speakers

Dr. Mohammad Shahidehpour, Illinois Institute of Technology

Dr. Kumar Venayagamoorthy, Clemson University

Dr. Scott Backhaus, Los Alamos National Laboratory

Mr. Robert Weich, Schneider Electric
DC Microgrids in Smart Cities: Economic Operation and Enhancement of Resilience by Hierarchical Control, Mohammad Shahidehpour, Illinois Institute of Technology
## Metrics For Comparing DC and AC Microgrids

<table>
<thead>
<tr>
<th>Metric</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Cost</td>
<td>No export (advantage to DC), Export/Import (~same)</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>No export (advantage to DC), Export/Import (~same)</td>
</tr>
<tr>
<td>Engineering Cost</td>
<td>Not assess in detail—potential advantage to DC</td>
</tr>
<tr>
<td>Reliability</td>
<td>No significant difference—spares at AC-DC interface</td>
</tr>
<tr>
<td>Resilience</td>
<td>No significant difference</td>
</tr>
<tr>
<td>Power Quality</td>
<td>Advantage to DC</td>
</tr>
<tr>
<td>Safety and Protection</td>
<td>No significant difference</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>No export (3% advantage DC), Export/Import (~same)</td>
</tr>
<tr>
<td>Environmental</td>
<td>Same as Energy Efficiency</td>
</tr>
</tbody>
</table>
Implementing and Enabling Business Model for DC Microgrids,
Robert F. Lachenmayer Jr.(Robert Weich), Schneider Electric

What Benefits can DC provide?

- Up to **90% less losses** and the potential for up to 20% – 30% cost savings.
- For new microgrids, **DC costs 50% less** than its AC counterpart.
- DC systems are more reliable (in part because there are fewer potential failure points);
  - The reliability of 380 VDC with regulated bus availability was 0.999998 with **200% improvement** compared to 208 VAC systems,
  - The 380 VDC with direct connect to battery bus availability was 0.9999996 with **1000% improvement**.

Technical Sessions (1)

- Rural and Off Grid DC Microgrid and Nanogrid
  - 3 presentations, All from India
- Performance Analysis and Optimization
  - 7 presentations, US/Germany/Denmark/China/US/US/Canada
- DC Microgrids in Residential and Commercial Buildings (1)
  - 4 presentations, Germany-Netherlands/US/US/US
- DC Microgrids in Residential and Commercial Buildings (2)
  - 4 presentations, US/Thailand-US/Netherlands/Netherlands
- Distribution Energy Generation & Integration (1)
  - 3 presentations, US/India/Denmark
- Distribution Energy Generation & Integration (2)
  - 4 presentations, US/China/Netherlands-China/Denmark-Spain
- DC Microgrids in Residential and Commercial Buildings (3)
  - 6 presentations, Germany/China/Brazil/Denmark-China/US/US
- Panel: DC Power for Data Centers
  - 5 panelists, Japan/US/US/US/US
Technical Sessions (2)

• Real-Time Monitoring and Control
  – 4 presentations, Italy-Denmark/Finland/US/Egypt
• Communication and Security Analysis
  – 5 presentations, US/UK-China/US/Italy-Switzerland/US
• Protection and Switching Techniques (1)
  – 4 presentations, France/Germany/China/US
• Protection and Switching Techniques (2)
  – 5 presentations, US/China/US/Netherlands/Netherlands
• Advanced Power Electronics (1)
  – 3 presentations, US/US/India
• Advanced Power Electronics (2)
  – 5 presentations, US/US/Brazil/Canada/US
• Local DC Power in Transport Sector
  – 3 presentations, US/US/Denmark
• Storage Technology
  – 3 presentations, New Zealand/New Zealand/Italy
Brown-out: 90% Load shedding

- Brown-out: only 10% power
  - Prevent overload by ensuring no home draws > 10%
  - Existing AC line (unlimited power) cut-off during BO
  - A new DC micro-grid with limited power (10%) but always ON
    - ON during Normal + Brown-out state
  
- Uninterrupted DC micro-grid will create a market pull for DC appliances
Analysis of Emerging Technology for DC-Enabled Smart Homes, Alexander Brissette, ABB Inc.

Hybrid AC/DC Topologies
Example 2

- AC to 380Vdc backbone
- 380Vdc backbone to 48Vdc/±24Vdc subnetworks
- Large/motor loads served separately
- DC bus for PV MPPT into 380Vdc backbone

Pros:
  - Advances use of DC
  - 380Vdc proven in datacenters

Cons: Safety concerns
Summary

DC power systems can support higher building energy efficiency

- 2% utility power savings have been demonstrated at 2 kW
- 5% utility power savings are seen as potential for P > 8 kW
- Consider 2-phase DC grids to compete with 3-phase AC
DC Local Power Distribution with Microgrids and Nanogrids,
Bruce Nordman, Lawrence Berkeley National Laboratory

Grid terminology

• **Microgrid**  
  Capability
  “...a group of interconnected loads and distributed energy resources ... . A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode”  
  *(US Dept. of Energy)*
  *CIGRE defn. includes microgrids never connected to utility grid*

• **Nanogrid**  
  Simplicity
  “A **single domain of power**; single voltage, frequency (if AC), reliability, quality, capacity (power), price, and administration. Storage is internal to a nanogrid.”  
  *Generation forms its own nanogrid.*  
  *(Nordman, 2010)*

• **Picogrid**  
  Singularity
  An **individual device with its own internal battery** for operation when external sources are not available or not preferred, and managed use of the battery.  
  *(S. Ghai et al. in e-energy 2013; paraphrased)*
Integrating Storage and Renewable Energy Sources Into a DC Microgrid
Using High Gain DC DC Boost Converters,
Gene Krzywinski, eIQ Energy, Inc.

The Parallel Advantage

<table>
<thead>
<tr>
<th>Conventional Series Strings</th>
<th>Parallel DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panels and strings must match</td>
<td>No matching or balancing required</td>
</tr>
<tr>
<td>Weakest panel sets performance</td>
<td>Each panel is independent</td>
</tr>
<tr>
<td>Panel voltage drives system design</td>
<td>Site conditions drive system design</td>
</tr>
<tr>
<td>Centrally set operating point</td>
<td>Each panel is optimized</td>
</tr>
</tbody>
</table>

Design limits: 7 more panels
600V Limit 3,600W

Design limits: 32 more panels
30A Limit 9,600W
Speakers Affiliations (1)

- JP: NTT Facilities, Sony CSL
- It: Tamil Nadu Energy Development Agency, Cygni Energy Private Limited
- Ch: CGN Solar Energy Dev.(3), State Grid Co.(2),
- Ca: ARDA Power(2),
- NL: Philips Res.(2),
- Ge: Fraunhofer Inst.(3), Siemens, ETA,
- Fr: Ampere Lab., Mersen,
- Br: CEFET-MG,
Speakers Affiliations (2)

- De: Aalborg U. (7),
- It: U di Palermo, Politecnico di Milano, U. degli Studi di Salerno, U. di Pisa,
- Fi: Lappeenranta U of T,
- Arab: Arab Academy of Science
- In: Indian Inst of Tech(5)
- NL: Eindhoven U. , Delft U.(4),
- Ch: Xiamen U.(3), Ziejiang U., Donghua U., North China Electric Power U.,
- UK: Aston U.
- Sw: Swizerland Center for Elec. and Microtech.,
- Th: Chiang Mai Rajabhat U., U. Phayao,
- Br: U Federal de Santa Catarina, U. Federal de Minas Gerais,
- Sp: Univ. Politecnica de Catalnya,
- NZ: U. of Waikato(2),
Thank you for Inspiration

We are like tenant farmers chopping down the fence around our house for fuel when we should be using Nature’s inexhaustible sources of energy — sun, wind and tide. I’d put my money on the sun and solar energy. What a source of power! I hope we don’t have to wait until oil and coal run out before we tackle that.

• Thomas Alva Edison, 1931