Committee Chair

Protecting Distributed Renewable Energy Resources with Direct Current Circuit Breakers

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Introduction and Background

- Repetitive conversion between AC and DC is inefficient and expensive.
- Increasing share of electricity is generated in DC or other variable forms, and nearly all consumer energy is DC.
- Bidirectional medium-voltage distribution systems enable harvesting clean and sustainable energy from wind, sun, and sea while promoting a more robust and adaptive infrastructure to our ever-changing global energy needs.
- The greatest challenge to DC distribution is safely interrupting fault current in the event of a short circuit.

Research Statement

- To develop high-speed, high-efficiency, and scalable protection devices for medium-voltage, bidirectional, DC power flow. These technologies will facilitate the harness and transmission of distributed renewable energy resources and their delivery to the end customer.

Focus Objectives

Develop bidirectional DC protection devices with:
- Minimal or no on-state energy consumption
- No communication, standalone operability
- Ultra-fast operational time, under 1 millisecond

Critical analysis DC distribution and protection for:
- Barriers to entry outside of protection devices
- Deployment into the Microgrid

Selected References


[3] Images collected from Various Sources. All original authors are given credit for their work. Citations available upon request.

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Motivation

- The entire world is shifting towards DC from AC. Electric Vehicles, LED lighting, portable electronics, and inverter motor drives are expanding in popularity, while photovoltaic systems, battery storage, and offshore energy harvesting are growing exponentially.

- Numerous inefficient conversions between AC and DC can be mitigated through DC distribution and protection.

- AC periodically crosses zero, this is not guaranteed for DC, complicating protection schemes.

ENABLING THE FUTURE OF ENERGY: DC MICROGRIDS

Performance Metrics of Progressively Switched and Actively Damped Hybrid DCCB

<table>
<thead>
<tr>
<th>Metric</th>
<th>Progressively Switched</th>
<th>Actively Damped</th>
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<tbody>
<tr>
<td>Single-stage Rectifier</td>
<td>3.5 V</td>
<td>3.6 V</td>
</tr>
<tr>
<td>Single-stage Transformer</td>
<td>5.6 V</td>
<td>5.7 V</td>
</tr>
<tr>
<td>Dual-stage Rectifier</td>
<td>7.1 V</td>
<td>7.2 V</td>
</tr>
<tr>
<td>Dual-stage Transformer</td>
<td>9.2 V</td>
<td>9.3 V</td>
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Hybrid DC Circuit Breakers (DCCB)

- Operating Mechanism of Hybrid DCCBs
- Combine Solid State and Mechanical – Efficient and Fast

Progressive Switched Main Breaker (MB) for Faster Fault Isolation

- Dielectric Matching – Limits Fault

PROGRESSIVE HYBRID DCCB: A NEW VISION

Next Generation Switching and Control Schemes

- Differential Adaptive Control – Accelerated Isolation

CONCLUSIONS AND FUTURE WORK

- Analyze potential of Hybrid DCCBs in non-conventional applications:
  - Industrial facilities
  - Multi-terminal DC distribution
  - Electric Ships
  - Data Centers and Server Farms
  - Redirect fault energy to operate gate driver and Thermal Cool Actuator (TCA)
  - Implement small scale rural DC Microgrid prototype in Bangladesh
  - Completely renewable DC design
  - Islanded / Grid-tied applications

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