

Microgrids for Energy Security and Resilience in Defence Applications

Natural Resources Canada
Ressources naturelles Canada

Canada



Overview

- Background
- Defence-specific challenges
- Dual-use applications
- De-risking through standards and testing
- Conclusion

Background

Context

- The world we live in is experiencing major technological changes and climatic and geopolitics perturbations.
- This forces countries to rethink their military strategy and investments.
- This means, amongst others,
  - Upgrading military installations to improve their resilience and autonomy,
  - Accommodating load growth (e.g., data centres, EVs, high-energy weapons),
  - Asserting land sovereignty in remote regions (e.g., the Arctic), and
  - Reducing global emissions of the defence sector.
- Experts are solicited to support the defence in applying microgrids as one of the solutions to these needs.

Energy Context

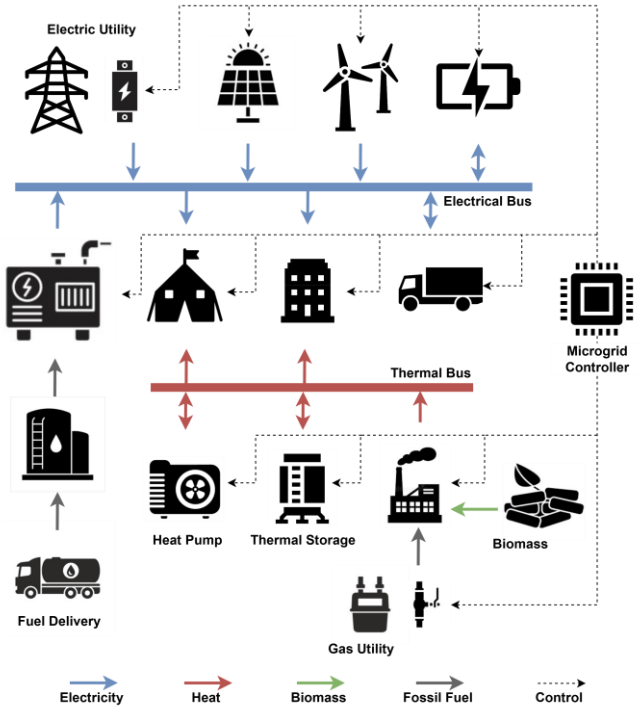
- Defence activities are heavily dependent on reliable sources of energy.
- Contrary to many other sectors of activities, military activities generally increase during catastrophic events.
- Energy supply lines (electricity, gas, fuel) are vulnerable to
  - Accidents (e.g., bus crash in a transmission tower [1])
  - Natural disasters (e.g., forest fires, earthquakes)
  - Extreme weather events (e.g., ice storm [2], floods)
  - Systemic failures (e.g., cascading effect of a bug or design flaw [3])
  - Cyber and physical attacks (e.g., sabotage [4], drone)
- Continuation of operations requires alternate sources of power.

Status

- Current military practices is to rely on liquid fuel (diesel and/or kerosene) for their autonomous operations and emergency needs in electricity and heat.
- Electricity is provided by generator sets that are generally not configured in a network but mostly operated individually for specific loads.
- Fossil fuel delivery is also vulnerable to supply perturbations and refuelling convoys are a primary target for physical attacks.
- Reducing fuel consumption saves soldiers lives [4] and reduce emissions.

Benefits of Microgrids in Defence Applications

- Redundancy of sources improves reliability.
- On-site renewables extend fuel autonomy.
- Storage and on-site renewables extend quiet operation duration.
- Microgrids provide flexibility and modularity.
- Interconnection of sources improve utilization factor and performance.
- Simplified interconnection with local grids and other microgrids.
- DC storage and generators can also be used for DC loads with fewer conversion losses.



Defence Energy Security Needs

Mindset

- **Assume degraded conditions**
  External resources can be cut by accident, environment or adversary actions
- **People-centred trust**
  Human judgement and presence are often prioritized over technology
- **Prioritize adaptability**
  Prefer flexibility and resilience over performance optimization
- **Execution focus**
  Emphasis on rapid action, and on-the-ground problem solving
- **Security as a primary constraint**
  Mission assurance outweighs cost and environmental considerations

Types of Operations

Bases

- Fixed installation connected to utilities
- In peace time, bases focus on training, deterrence, and routine readiness
- In wartime, bases act as staging areas, logistical hubs, and launch pads for active combat operations

Deployed Camps

- Semi-permanent installations (weeks to years) deployed in the field as a base camp for operations
- Camps may not have utility connections
- Camps can provide power and energy for tactical weapons and vehicles

Bases

Requirements

- Continuous operation in case of disruption of one or more utilities
- Autonomy for multiple days or weeks
- Clear separation of critical, essential and non-essential loads
- Flexibility to reconfigure

Challenges

- Large electrical and thermal base loads
- Can be intertwined with civilian installations/workers
- Compliance with rules and regulations
- Difficult to estimate the wartime load
- Constant evolution

Opportunities

- Multiple utilities available
- Time for planning
- Few space/weight constraints
- Higher tolerance to complexity
- Access to broad expertise
- Training ground for microgrid personnel

Deployed Camps

Requirements

- High reliability
- Easy to deploy, adapt and operate
- Interoperability with different standards (international)
- Capability to power or recharge tactical equipment

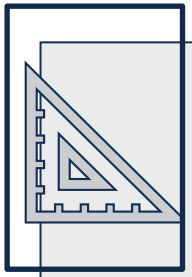
Challenges

- Need a power source to provide the base load
- Need for mobility limits the equipment choice
- Onsite crew must be self-sufficient
- Frequent changes need to be implemented quickly

Opportunities

- Efficiency improvements translate in extended autonomy
- Combining resources with allies

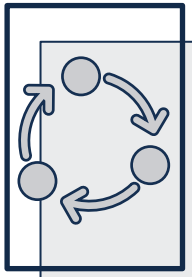
Cross-Cutting Challenges



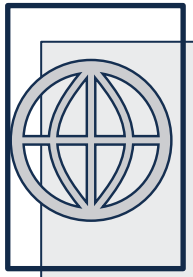
Current microgrid controllers and systems are often highly engineered on a case-by-case basis.



Microgrid vendor's solutions are often proprietary.



Solutions target fixed installations and lack ease of reconfigurability.



National standards for sources and loads connection, voltage and frequency are different and often not compatible.

Opportunities for academia, research facilities and manufacturers to develop and derisk plug and play and flexible microgrid solutions.

What is Happening

- Utilities are developing and implementing microgrids to improve their resilience and reduce their emissions by facilitating distributed energy resources integrations.
- Similarly, microgrids are considered by defence departments to improve their resilience to external resources and reach their emissions target, for example:
  - Successful examples of implementation [6] in San Nicolas Island, Naval Station Rota, Fort Hunter Liggett, Marine Corps Air Station Miramar and others
  - Energy Resilience and Conservation Investment Program (ERCIP) [7]
  - Advanced Microgrids towards Arctic Zero Emissions (AMAZE) [8]
  - RAF Invests in Off-Grid Energy to Strengthen Operational Resilience [9]
- NATO has shown interest in microgrids for their operations to increase security, reduce emissions and facilitate interoperability of equipment of multiple nations:
  - Energy Security Topic [10]
  - NATO Energy Security Centre of Excellence [11]

Dual Use

The Case for Dual Use

- **Cost-Efficiency**
  Co-developing and reusing avoid duplication of R&D.
- **Accelerated Time-to-Field**
  Adapting commercially available solutions is faster than building from scratch.
- **Access to Cutting-Edge Innovation**
  Private sector R&D in fast-moving fields can be more dynamic and adaptable than rigid defence programs.
- **Economic Resilience**
  Broader market reach translates into revenue stability for developers and manufacturers.
- **Sovereignty & Security**
  Nurturing domestic companies that build dual-use technologies reduces reliance on foreign suppliers.



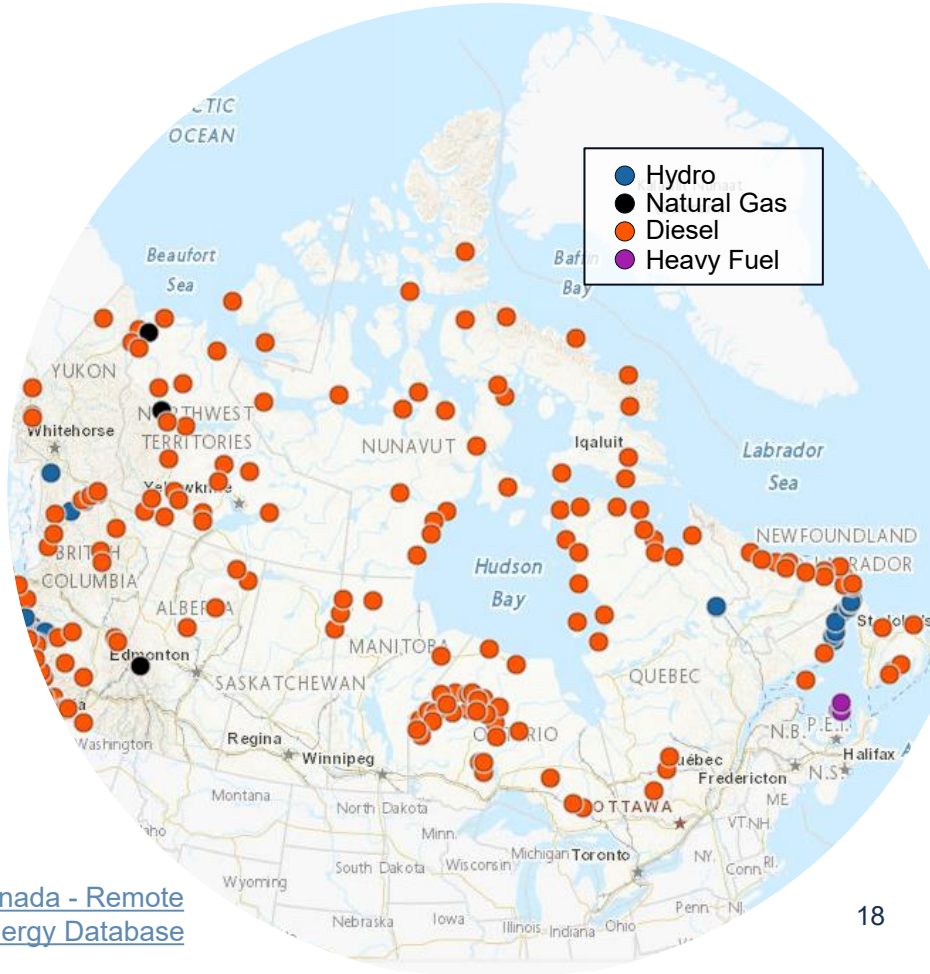
Helsinki Airport - Google Maps

Critical Infrastructures

- Critical civilian infrastructures share need very similar to bases. These include:
  - Hospitals,
  - Data centres,
  - Airports,
  - Water pumping stations, and
  - Telecommunication.

Remote Communities and Facilities

- Remote applications share need very similar to a combination of deployed camps and bases.
- They need a power source for the base load, but they have the benefits of being permanent installations.
- They include:
  - Remote communities,
  - Isolated mining sites, and
  - Equipment deployed in the field.

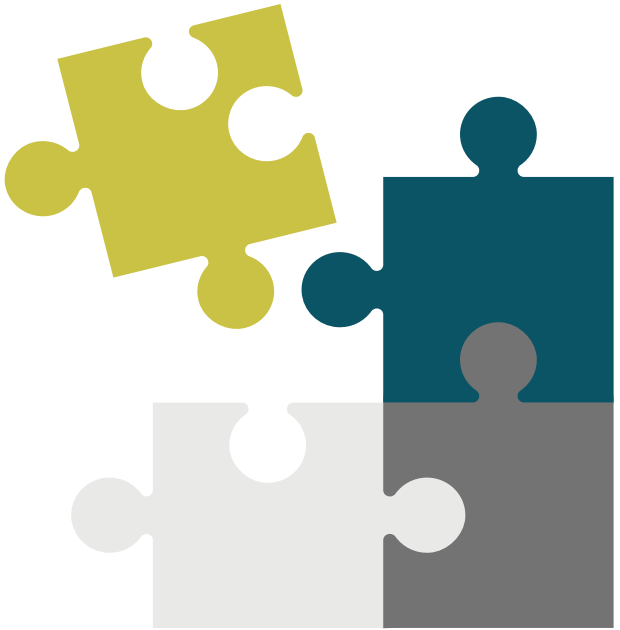


The Atlas of Canada - Remote Communities Energy Database

De-Risking

Standards and Guidelines

- Avoid reinventing the wheel.
- Contain the result of experience (good and bad) from multiple stakeholders.
- Grounded in available technology and evolve with it.
- Facilitate interoperability.
- Can be combined and adapted to specific need.



Examples

- **UFC 3-550-04** – Resilient Installation Microgrid Design
- **MIL-STD-3071** – Tactical Microgrid Communications and Control
- **STANAG 4133** – Electrical Power Supplies: Standard Types and Rotating Generating Sets
- **IEC 60309 series** on industrial plugs/sockets with voltage color coding
- **IEC 61850 series** on communication protocols for intelligent electronic devices used in power systems
- **IEC 62898 series** on microgrid planning, specification, design and operation
- **IEEE 2030 series** covering communication, microgrid controllers' specification and testing as well as planning and design of microgrids
- Microgrid Handbook for Army Resilience, PNNL [12]

Smart Grid and Microgrid Electrical and Thermal Research Facility

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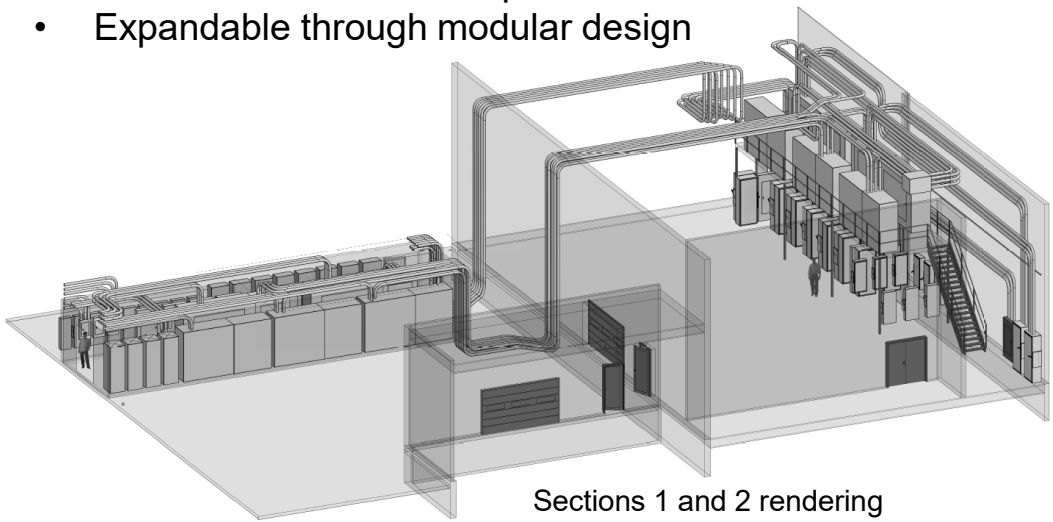
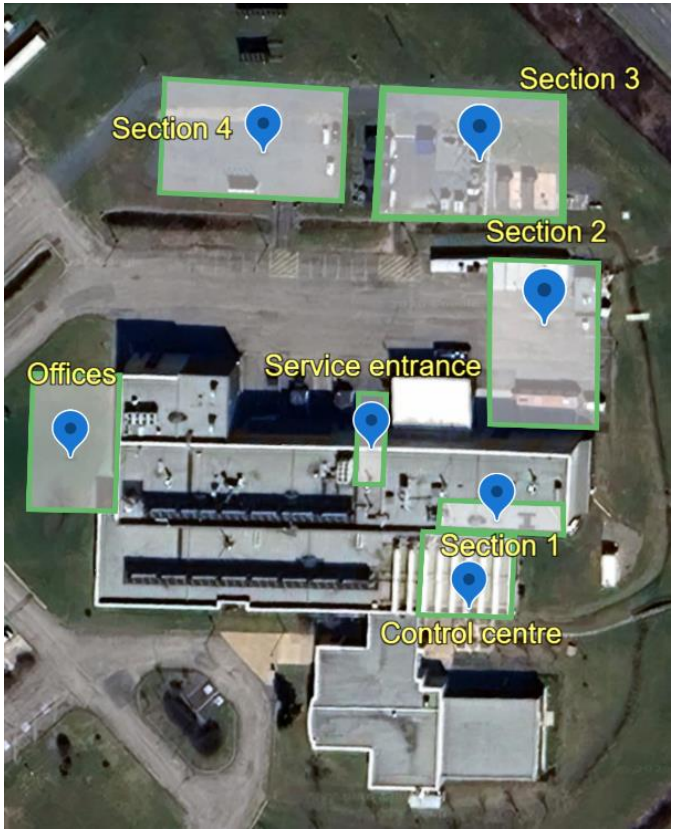
- Smart grid, microgrid, multi-microgrid
- Flexible to test multiple configurations
- Hardware in the loop capable
- Electrical and thermal aspects
- Expandable through modular design



Sections 1 and 2 rendering



Site overview

Conclusion

Key Points

- Microgrids have the capability to **enhance energy autonomy, reliability** and **flexibility**.
- Most individual **technologies** are already **mature**, but their **applications** are still considered **innovative** in microgrid deployment.
- The biggest challenges are **interoperability** and **reconfigurability**.
- Civilian and military microgrids share common **technical** and **regulatory** opportunities and challenges.

Microgrid Main Benefits



References

[1] Bus crashes into electrical pylon, causing massive power outage on the South Shore, CTV News, Canada, July 2024. Online: https://www.ctvnews.ca/montreal/article/bus-crashes-into-electrical-pylon-causing-massive-power-outage-on-the-south-shore/

[2] 25th anniversary of ice storm brings back chilling memories for Quebecers, CBC news, Canada, January 2023. Online: https://www.cbc.ca/news/canada/montreal/ice-storm-25-anniversary-quebec-1.6703087

[3] 28 April Blackout in Spain and Portugal: Expert Panel releases comprehensive factual report, ENTSO-e, EU, October 2025. Online: https://www.entsoe.eu/news/2025/10/03/28-april-blackout-in-spain-and-portugal-expert-panel-releases-comprehensive-factual-report/

[4] Berlin outage highlights German vulnerability to sabotage, BBC, Germany, January 2026. Online: https://www.bbc.com/news/articles/cvgrpzn6gz4o

[5] Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys, Defence Tactical Information Center, USA, September 2009. Online: https://apps.dtic.mil/sti/citations/ADB356341

[6] Microgrid Case Studies: Successful Implementation Resulting in Resilient and Secure Infrastructure and Facilities, US DOE, USA, August 2025, https://www.energy.gov/sites/default/files/2025-08/femp_summer_camp_t2_s6_slides.pdf

References (cont'd)

[7] Energy Resilience and Conservation Investment Program (ERCIP), USA. Website: https://www.acq.osd.mil/eie/ero/ier/ercip.html

[8] DRDC continues to AMAZE with Arctic emissions reduction research, Defence Research and Development Canada, Canada, December 2024. Online: https://science.gc.ca/site/science/en/blogs/defence-and-security-science/drdc-continues-amaze-arctic-emissions-reduction-research

[9] RAF Invests in Off-Grid Energy to Strengthen Operational Resilience, Royal Air Force, UK, May 2026, Online: https://www.raf.mod.uk/news/articles/raf-invests-in-off-grid-energy-to-strengthen-operational-resilience/

[10] NATO Topic: Energy security, NATO. Online: https://www.nato.int/en/what-we-do/wider-activities/energy-security

[11] NATO Energy Security Centre of Excellence, Lithuania. Website: https://www.enseccoe.org/en/

[12] Microgrid Handbook for Army Resilience – A Technical Review, PNNL, USA, October 2025. Online: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-38494.pdf



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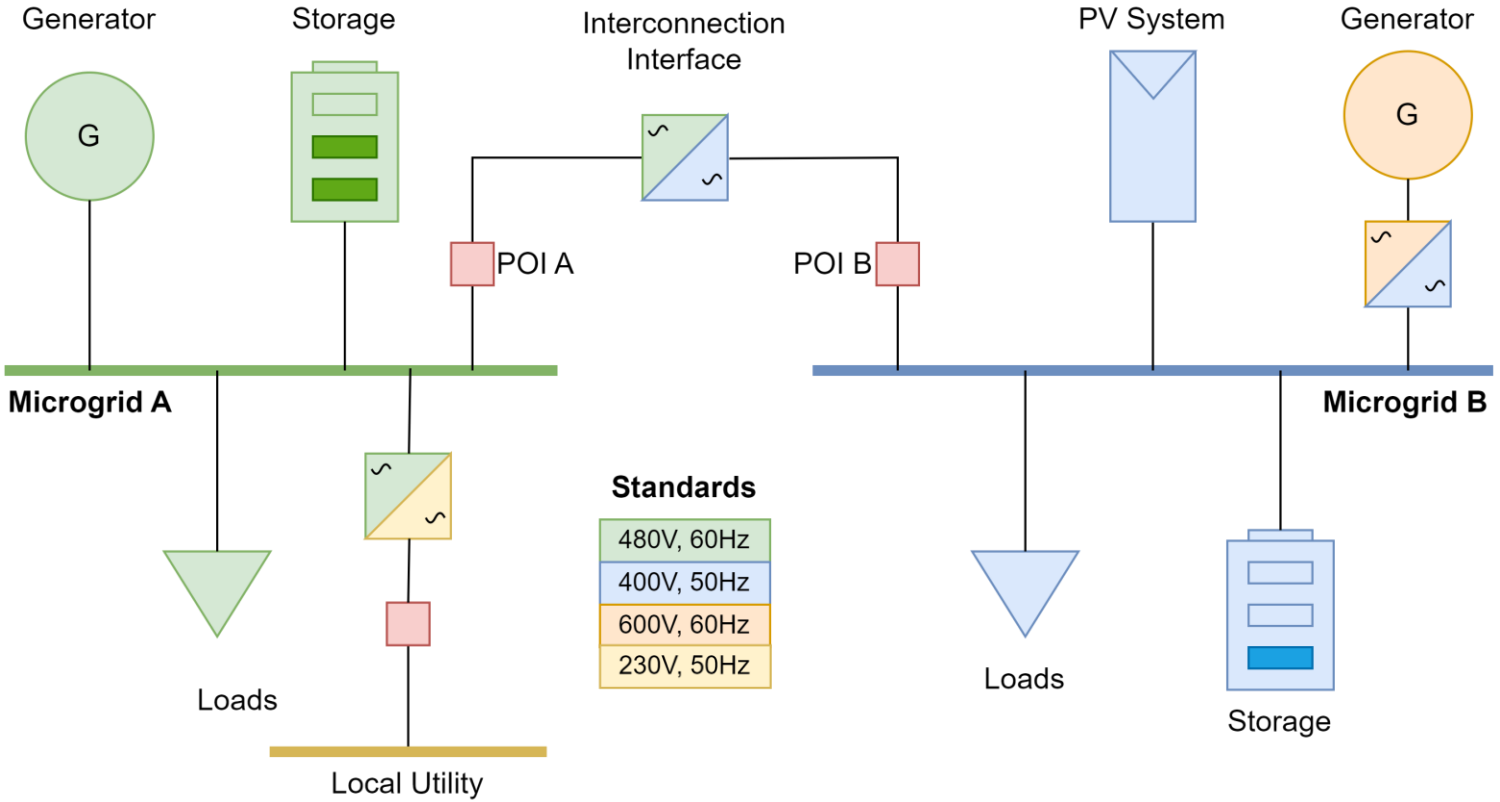
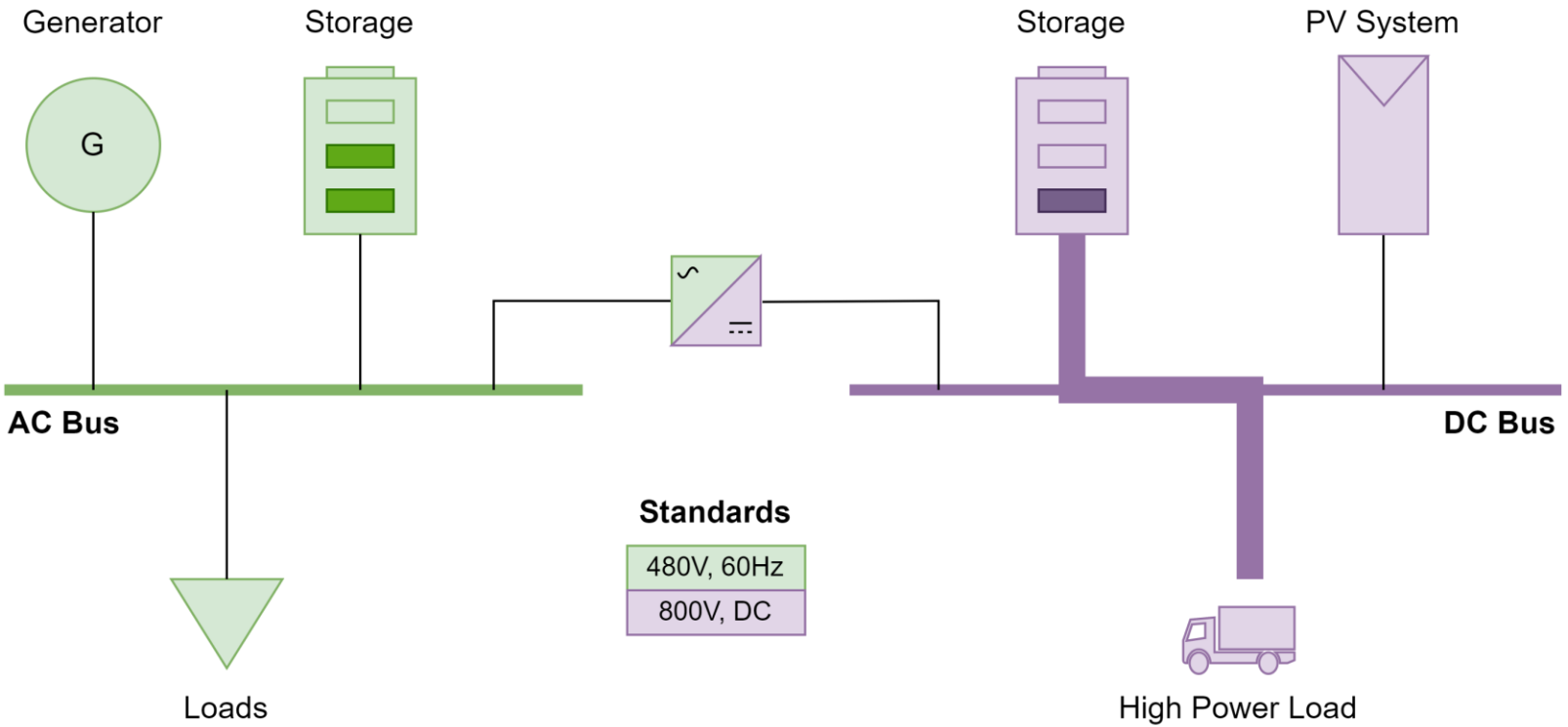
Appendix

Power Converters in Interconnection



AC/DC Microgrid for High Power Applications



CanmetENERGY Test Facility Concept

