SUMMARY

Handbook on Microgrids for Power Quality and Connectivity

Off-grid minigrids bring electricity to remote rural or island communities, while grid-connected microgrids can enhance reliability and resilience of power supply, especially for commercial and industrial users. Photo credit: ADB.

Here’s a guide to the applications, technologies, business models, and regulations that should be considered in deploying a microgrid system.

Published: 01 September 2020

Overview

Microgrids have a critical role in transforming energy systems by contributing to the energy 5Ds—decreasing consumption, decentralization, decarbonization, digitalization, and disintermediation.

Microgrids are a type of distributed energy system that can be connected to the main regional or national electric grid (synchronous with the grid). Or it can be disconnected and operate autonomously (island mode). A microgrid is a localized group of interconnected loads and distributed energy resources (e.g., renewables) within clearly defined electrical boundaries (e.g., cities, communities, campuses) that act as a single controllable entity. It is established primarily for local reliability, resilience, and operational economics.

A related setup called minigrid uses similar technology and components. Though referred to interchangeably with microgrids, minigrids are actually a distinct subset of microgrids. These isolated, small-scale distribution networks are essentially a microgrid disconnected from larger electric grids, which provide power to a localized group of customers and produce electricity from small generators, often coupled with energy storage systems.

Currently, majority of the world's microgrids are in North America and the Asia and Pacific region. Most of the capacity in the Asia–Pacific is in the People's Republic of China and Japan.

This is an adapted summary of the Asian Development Bank's *Handbook on Microgrids for Power Quality and Connectivity*, which serves as a guide to evaluate the feasibility of microgrid systems in enhancing power supply quality and connectivity. The handbook includes information about on-grid microgrids for urban and industrial applications, prevailing business models, case studies of microgrid deployment, and emerging trends that could shape the future of this sector.

Key Benefits

In the context of grid-connected microgrids, there are traditionally three core value propositions to the end user, although the exact combination of value drivers varies from case to case—access to electricity (social), fuel and cost savings (economic), and emission reductions (environmental). Fuel independence and uninterrupted supply and/or reliability (operational) are important value propositions too. The total value of a microgrid, hence, encompasses its power generation savings, grid services, reliability and resilience, and environmental benefits and value to the distribution grid.

However, grid-connected microgrids have not yet achieved significant scale, mainly because of the (i) limited number of scalable prototypes, and lack of translatable performance metrics; (ii) limited experience in scalable microgrid financing models; (iii) regulatory bottlenecks arising out of restrictions on utility franchise rights and retail market access; (iv) cybersecurity concerns and limited technical standards and interconnection protocols; and (v) technical and operational challenges, such as power quality, control architecture, grid synchronization and stability, and energy management.

Microgrid projects in developing countries can provide gains and benefits beyond solely the energy access benefit that remote off-grid minigrids provide. A key benefit that is often overlooked by policymakers is the collateral benefit of reliability and resilience of electricity supply that grid-connected microgrids, especially commercial and industrial microgrids, can provide. This is especially important as a disaster resilience strategy, particularly in the context of increased risk of natural disasters because of climate change.

Designing a Microgrid

Microgrids must have the ability to maintain a balance between available supply and desirable load demand through careful marriage of supply and demand combined with intelligent control. The main components of a microgrid are (i) local generation, (ii) end-use loads and demand-side energy management, (iii) energy storage, (iv) microgrid monitoring and control system, (v) utility interconnection, and (vi) other components like power electronics and protection.

In terms of design architecture, microgrids can be classified in two ways—by their control approach, and by their power technology. Under the control approach, there can be centralized and decentralized management systems based on number of entities responsible for decision-making processes and a single point of failure. Under power technology, the microgrid systems can be alternating current, direct current, or hybrid systems.

From a project management perspective, the conceptualization, evaluation, design, construction, and commissioning of a microgrid follows the same broad stages as other infrastructure projects with similar stakeholders. In the case of an existing facility or brownfield microgrid, the pre-project evaluation begins with the assessment of current situation, followed by high-level assessment for both brownfield and greenfield projects.

The subsequent project feasibility study should typically consider the applicable policy and regulatory framework, renewable energy resource assessment, assessment of site conditions and site selection, technical viability, financial viability, and financing structure.

Business Models

The business models employed for grid-connected microgrids (including technology, financing, and stakeholders) to meet relevant pricing options and financing implications can be: (i) customer-owned (up-front capital investment), (ii) renewable energy service company (RESCO)-owned, (iii) utility-owned, (iv) cooperative-owned, (v) community-owned, (vi) pay-as-you-go (typically rural remote minigrids), and (vii) remote (off-grid).

The choice of business model, through which the microgrid asset is built, operated, and maintained, is an important pre-development consideration irrespective of technology choice. Business model choices are typically between up-front capital investment model and RESCO model. Within the RESCO model, variations exist, such as build-own-operate, build-own-operate-transfer, lease-to-own, and power purchase agreement models.

A financial and economic analysis of microgrids requires a study of their benefits and costs to the microgrid owner or operator, the utility or distribution network operator, and/or the end user. Microgrid value is typically shared among utilities, end users, third parties, or co-owners depending on the ownership and operating model. Financial analysis of different kinds of business models are conducted using a combination of these various methodologies—net present value, financial internal rate of return, and sensitivity analysis.

Some of the key policy and regulatory enablers for urban and/or industrial microgrids in developing countries would potentially include:

i. specific urban and/or industrial microgrid policies at national and/or provincial levels,
ii. net metering or gross metering policies,
iii. technical standards and specifications for grid interconnection,
iv. open access or contestable consumer policies, and
v. financial risk-sharing mechanisms for debt financing.

The Future of Electricity

Microgrids are poised to play a big role in the electricity ecosystem of the future with decarbonization, digitalization, decentralization, and non-wires solutions being its key attributes. They could help address today's energy challenges, including an optimized way to access reliable, resilient, clean energy that can defer or replace the need for specific equipment upgrades, such as new transmission lines or transformers, by reducing the load at substation or circuit level.

While there is also a case for continued addition of transmission line capacity, particularly in the context of high-level penetration of renewable energy (which are almost always intermittent) to be the backbone of the electricity system, the following also need to be considered:

i. Good solar and wind resources are often at different locations.
ii. Generating electricity from renewables requires a lot of land and such land availability tends to be further away from population and load centers.
iii. Electrification of the transport sector would likely require additional transmission capacity.

However, as a holistic strategy, if the intent is to increase the level of renewable energy penetration in the grid, then adding transmission capacity needs to be considered in the context of, and as a complement to, grid edge investments in distribution networks and microgrids.

Microgrids also hold key relevance to the transportation sector, which consumes over 30% of primary energy. Electrifying only a small percentage of this in the coming years would translate to significant capacity. A decentralized infrastructure will allow the many actors in the electric vehicle (EV) ecosystem to capitalize on the flexibility of EVs—one promising way to do this being "vehicle-to-grid" (V2G), wherein EVs can sell demand-response services to the power grid.

Microgrids are quite relevant to the current power system situation in Asia and the Pacific. In general, power consuming end users in developing countries typically do not have access to high-quality reliable power and must contend with frequent power outages, in contrast to their counterparts in developed countries. Developing countries also often have weak grid infrastructure due to under-investment and poor management, leading to high power losses and theft, thereby hindering the success of business and industry. This is the value proposition of grid-connected microgrids in developing countries.

Furthermore, grid-connected microgrids are the building blocks of smart grids and smart supergrids, which have the potential to help developing countries leapfrog.

From a policy and regulatory standpoint, governments, and policymakers in developing countries in the region should aim to include microgrids (both on-grid and off-gird) in their power system planning and design. Specific policies and regulations to clarify microgrid as a distinct power asset class and their technical standards in terms of grid interconnection would go a long way in incentivizing microgrid investments. Clarity on tariffs, licensing, and permitting for microgrids would also be beneficial, while targeted concessional lines of credit and financial risk-sharing facilities from development finance institutions would help increase access to finance for microgrids.

Smart grids are evolving because of the increased proliferation of distributed energy resources, demand-side management, energy storage, and decentralized networks such as microgrids. There is significant potential for cost, efficiency, and resource utilization improvements by enabling market-based transactions between energy producers and consumers. Some of these transactive energy arrangements can be based on peer-to-peer energy trading and blockchain technologies. Smart grid is an important application of Internet of Things, which, along with data analytics and artificial intelligence, may have benefits for microgrid capabilities and techno-commercial viability.

Contents

1. Main Technologies of Renewable Distributed Generators
2. Main Technologies of Nonrenewable Distributed Generators
3. Main Technologies of Storage Systems Used in Microgrids
4. Standards for Alternating Current and Direct Current Microgrids
5. Alternating Current and Direct Current Microgrid Control Strategies
6. Transactive Energy Case Studies Summary
7. Blockchain Smart Contracts
8. Blockchain Microgrid Use Case
9. Bottom-Up Decision-Making Process on Using Blockchain
10. Business Models – Detailed Description

Resources

Asian Development Bank. 2020. *Handbook on Microgrids for Power Quality and Connectivity*. Manila.

Yongping Zhai
Former Chief of Energy Sector Group, Sustainable Development and Climate Change Department, Asian Development Bank

Yongping Zhai worked on energy development in Asia and Africa for 30 years. He was in charge of overall energy policy coordination and technical support to ADB energy sector operations. He was also in charge of developing energy sector knowledge work for ADB and interacted with worldwide energy sector partners.