VIGYAN 2047 Volume 1 No. 3 December 2024 Pages 15–21

Microgrids – A Value-Based Solution for Emerging Economies

Kumudhini Ravindra

Energy Landscape in emerging countries

Energy forms a vital input and critical infrastructure for the economic development of countries and for improving the quality of life of people. The focus across the world has been to enable better access and use of modern energy sources, to ensure increased productivity, better livelihoods, and a higher standard of living. This translates to a growing demand for energy and energy services. Some of the key drivers shaping the increasing demand and state of the global energy supply in the 21st century are population growth; economic and social development resulting in an increase in individual expectation for energy; financial and institutional conditions; local, regional and global environmental concerns; efficiency of energy supply and use; technological innovation and deployment; dependency on fossil fuels and its limited availability; climate change and its relation to energy supply; geopolitical conditions; and access to modern energy in the developing world.

Issues with traditional solutions

Traditionally, energy needs are met by increasing supply centrally. The motivation for this choice is that centralized grid-based electricity is considered the most convenient, safe, highly efficient and reliable form of energy. The advantage of centralized grid-based systems is that they capitalize on the economies of scale, which is the focus of policy makers and power utilities. These systems are amenable to the

top-down policy making framework exercised by most decision makers with the standardized management structure. These systems are considered to have better quality standards. Innovation and R&D expenditures are also directed towards developing bigger and better systems.

Energy systems in emerging economies are plagued by problems like the poor performance of the power sector and traditional fuels, transition from traditional to modern economies, and structural deficiencies in society and economy. The growing demand for energy in these countries may not be met adequately by the centralized systems. Also, not all consumers are treated equally by energy utilities whose goals are higher profits and value realization. Load shedding[1], planned and unplanned brownouts are the response used by power utilities to secure the grid; deal with the shortages in short term energy supply and to discriminate consumers based on their ability to pay. Consumers powered in such manner may have to either invest in expensive backup systems to ensure acceptable power availability, quality and reliability, or go without power and end up with economic and social losses.

Centralized grid-based power systems are capital intensive and have long gestation periods. Difficulties in attracting such capital for energy investments impede economic development, especially in less developed countries. There is a fair amount of inertia with regard to the rate of change that can be introduced in the energy system. Decisions on centralized power plants are delinked from social and environmental aspects. There is an excessive focus on technology and economic aspects in the decision-making rather than on resources and their availability. Centralized power systems are considered to be highly efficient. However, it can be shown that for certain end-uses; it may be more efficient to use local energy resources than grid-based electricity when the overall efficiency of the energy chain is considered. Dependence on external sources and imports increases the vulnerability of the dependent regions and nations to geopolitics and reduction in energy security. Rising energy prices for importing energy, can lead to skyrocketing import bills, with adverse consequences for business, employment, and social welfare. The relationship between cost of the system and power quality & reliability (PQR) is exponential in nature. In order to improve PQR, redundancy needs to be introduced into the power system. There is an increasing order of magnitude of costs for every percentage point improvement in reliability.

Many a time, utilities are economically delinked from the demand side. Centralized power plants do not ensure access, affordability and energy security at the individual consumer and community level. The social and environmental impact of individual choices remains unknown. Engineering solutions are preferred to social solutions. On the microeconomic level, per unit energy prices influence consumer choices and behaviour, and this can affect macroeconomic development and growth.

Consumer Energy Needs

Addressing consumer energy needs with power systems is not just a technical problem as often perceived. It requires an understanding of the intricate nature of the energy system at the economic, social and environmental levels. It is about acknowledging individual consumers and communities as a significant part of the system with entitlements, rights and duties and that the power system exists for serving their needs. Strengthening communities to be self-sufficient or less dependent on grid power alone would reduce vulnerability while improving energy security at local levels.

What all consumers need are sustainable energy systems. All citizens in the world should have a right to access modern power. Consumers demand reliable and secure availability of quality power. This energy while being modern should not be detrimental to the environment or exacerbate climate change.

All this imply the need for efficient handling and balancing of the conflicting objectives of "Equity, Environment and Economy." Microgrids using renewable and clean energy resources with built-in demand response can be suitable decentralized alternatives to augment the centralized grid-based systems. Ideally, all distributed energy resources can be cast as microgrids. Similarly, all consumers or communities of consumers can be designed to operate as microgrids.

What are Microgrids?

The last two decades has seen an increased focus on Microgrids—both research and implementation. Microgrids is not a new concept. Historically, power grids developed as isolated systems, which were managed and controlled locally.

Microgrid is defined as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid (and can) connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode". (DOE, 2002). Microgrids include an integration and control of multiple local generation and storage assets (diesel generators, combustion turbines, PV arrays, battery systems, etc.) to provide on-site generation for local loads in both grid-tied and islanded modes of operation.

Thus, microgrids are being predominantly seen as (i) an off-grid solution to improving access to remote areas, (ii) a mechanism for locally improving the power quality and reliability of a specific consumer/ area, (iii) as a means of better control for the combination of different distributed energy resources connected to the grid from a grid perspective, and (iv) a means of operating in an islanded mode when connected to the grid. All these are true, but microgrids can be much more in the context of emerging economies where power systems have hardly made a dent in the economics of the region. Microgrids can be suitably designed to meet needs like access to modern energy, energy independence, local resource utilization, specific consumer end use requirements, livelihood generation, power quality and reliability requirements, sustainable development and their combinations.

Current global crises—climate crises, wars, susceptibility to terrorist attacks, energy security issues, breakdown of the grids at important junctures—all demand a new thinking. They challenge the existing worldview of 'bigger is better'. Suddenly having large power plants and extensive inter-connected grids did not seem such a smart move at all. Focus today is therefore shifting to smart grids that are able to self-heal, operate in islanded modes and able to use digital technologies. In all this, microgrids are touted as offering the potential of better control and management at the low voltage level. It is like transitioning back into the era of the small, isolated grids of the yester-years. The novelty however is in integration of IOT (internet of things), digital technologies and modern distributed renewable energy technologies.

In this context, microgrids can be re-defined as—

"a group of interconnected loads and distributed energy resources within clearly defined boundaries that acts as a single controllable entity

- designed on the basis of the local consumer's or communities' energy needs and end uses, where the loads and energy uses are qualified and segregated based on their reliability requirements;
- that optimally matches these end uses and locally available clean environmentally friendly energy resources without the need for transporting the fuel, with or without the grid;
- that may or may not be connected to the centralized grid;

Greenpeace India's solar project in Bihar.

- that can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode (if it is connected to the grid);
- that can communicate with the grid digital technologies to enable demand response and smart supply and demand side management."

Microgrids for emerging economies

Microgrid choice in emerging economies depends on central grid power availability; energy security needs of the region and at consumer levels, local conditions, techno-economic efficiency requirements, power quality and reliability requirements in the context of environmentally sustainable development. The growth perspectives[2] are towards expanding reach of power into off-grid areas, managing growth of existing systems and transforming growth of the new regions.

Microgrids are the power systems configuration providing clear economic and environmental benefits compared to expansion of legacy modern power systems. They benefit all sections of the society, facilitating people's access to modern energy resources and removing inequity in energy access. They empower people by allowing them a stake in their energy generation and distribution.

The taxonomy of the types of microgrids suitable for emerging markets are:

1. **Energy Independence Model** which focuses on independence from the Centralized Grid typically in areas which are remote or off-grid
2. **Resource based Model** where the emphasis is to maximize usage of locally available resources like solar, micro-hydel, wind and other naturally available energy resources
3. **End Use focused Model** for microgrids considers energy end uses of communities like illumination, cooking, and water pumping as the main criteria for the selection of the appropriate resources.
4. **Livelihood Model** based microgrids can be a means for improving livelihoods of poor communities by providing opportunities for increasing the skill base of the individuals
5. **SQRA based Microgrids** are the traditional kind of microgrids that enable local definition of Security, Power Quality, Reliability and Availability requirements and are designed for the same
6. **Environment Focused Model** based microgrids can be used for addressing environmental issues at community level – targeting the carbon credits and GHG certificates
7. Microgrids can also be designed for more than one purpose in which case a **Combination** of the above models can be used

Microgrids in India – some examples

An example of microgrid is by Greenpeace India in Bihar. The rural electrification micro-grid project is at the Dharnai Village in Jahanabad district of Bihar. This solar based technology model would have about 100 kilowatts of solar panels that will supply round the clock electricity to 350 households in Dharnai on affordable and sustainable basis.

Similar off-grid microgrid projects based on micro-hydro systems have been successfully installed in the western coastal regions of India by Prakruti Hydro Labs.

Globally an estimated 745 million people are without access to electricity. More than 80% of these people are in sub-Saharan African and almost all of them are in rural areas[3]. Microgrids due to their proximity to the consumer and the ability to use locally available energy resources have the potential to address specific *end-use needs* like illumination, cooking, etc.

Improvement in Livelihood as seen in Sunderban Islands

A case in point is the microgrid implementation in the Sagar Islands in the Sundarbans, seen in above figure. Several solar initiatives, wind-based systems and biogas systems have been installed in this remote area to meet the energy needs of the consumers. The Sagar Island's 11 solar stations can each produce between 25 kilowatts (kW) to 100 kW, totaling close to 800 kW, distributed via power lines 2 to 3 km long. They supply 1,400 households and commercial establishments. The generation cost is about Rs.10 ($0.20) per unit (1kWh), which is then sold for Rs.7 and difference of Rs.3 being borne by the West Bengal government.

Microgrids can also address *livelihood* issues of communities as demonstrated by the Gram Power microgrids and Gram Vikas Biogas based systems. These microgrids aim to provide reliable, affordable power to the poor. They also help skill building and ensure sustainable livelihoods in rural households.

Gram Power was involved in setting up India's first Solar Powered Smart Microgrid in the Rajasthan hamlet of Khareda Lakshmipura in March 2012, providing energy for rural households. Gram Power's core innovation is their Smart Distribution technology with Smart Meters and Grid Monitoring Systems to provide on-demand, theft-proof power with a unique pay-as-you-use schedule that is determined by the end user.

Biomass Energy for Rural India (BERI) Project, sponsored by GEF-UNDP, ICEF, Government of India and Government of Karnataka, a 500-kW biomass power plant established near Kabbigere village, is another initiative with an aim of implementing a decentralized bio-energy technology for rural India. It utilizes locally available biomass to supply quality and reliable power supply at reasonable price. The project also provide opportunity to create employment, improve agro & village industries and hence improve their livelihood. Even though the success of these types of projects depends on the various stakeholders, the main objective and spirit can be replicated in rural areas.

Microgrids can also be designed keeping in

Solar project in Jharkhand.

mind the type of *consumer* using the system. Many integrated gated communities and businesses, today, get their bulk power supply from microgrid installations. They are usually connected to a dedicated grid substation from the utility. And in case of disruption in grid supply, they use diesel generators for their needs as a distributed unit. Many a time they incorporate solar generation or other renewable energy options. These consumers are equipped with smart meters that connect into data concentrators at distribution transformers and feed near real-time usage information to their energy management systems. These microgrids also have inverters and storage batteries to ensure 24/7 power quality and reliability.

Defense installations and remote areas also have microgrids implemented. Such microgrid systems work independent of the grid. Here the loads are classified and segregated based on their criticality to improve performance under different conditions.

Microgrids are also aiding institutions and communities in participating actively in sustainable development by enabling use of locally available renewable resources like solar, wind and biomass to better manage their energy needs while demonstrating an ability to go green.

Value Realization from Microgrids

Microgrids, which in a way encapsulate the mindset – ‘small is beautiful’, are much more than a new age phenomenon. Microgrids enable the centralized grid operators and load dispatch centers to view them as single entities. This will enable better communication and management. Demand response has a greater meaning when used in conjunction with microgrids. Consumers can play a more active role defining their needs in such systems.

The value propositions of microgrids as put forth by DOE are (i) reduced cost of energy and better management of price volatility, (ii) increased resilience and security of power delivery, (iii) improved reliability and power quality, (iv) promotion of deployment and integration of energy efficient and environmentally friendly technologies, (v) assisting in optimizing the power delivery system, including the provision of services and (vi) service differentiation through different levels of service quality and value to customers segments at different price points.

The value created by microgrids can be multifold. In terms of technology, microgrids improve the efficiency, reliability, access, affordability and also enable local resource usage. Investing in local microgrids would create employment opportunities, livelihood options, as they require additional human capabilities and skills, which in turn require Education/ Training. This implies an increase in human and social capital creation. Given that microgrids provide access to modern power, there is an increase in the economic capital viz., GDP, FDI, and GNP of the region. When these systems use clean forms of energy, the natural capital of the regions are protected and improved. From all these perspectives, it can be said that microgrids are value-enriching systems that have to be supported by all stakeholders.

Future of Microgrids

Microgrids are not just a stopgap solution for matching demand-supply in emerging economies and enabling access to modern energy. In case of off-grid and remote areas, it is not to be assumed that microgrids will give way to centralized grids, if technologies make it possible. Microgrids have to be seen as value-based entities that co-exist with the centralized grid. They are potent entities that can operate essential services even in the case of emergencies like natural calamities as demonstrated by the Sendai microgrid when the 9.0-magnitude earthquake struck off the northeast coast of Japan and triggered one of the deadliest tsunamis[4] and the SDG&E's Borrego Springs Microgrid during the intense thunderstorms on Sept. 6, 2013[5]. They can be designed to be 'smart' to incorporate innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies. Microgrids can better facilitate the connection and operation of generators of all sizes and technologies; allow consumers to play a part in optimal operation of the system; provide consumers with greater information and choice of supply; significantly reduce the environmental impact of the whole electricity supply system; and deliver enhanced levels of reliability and security of supply at the local level.

Presently, the centralized grids interact with individual consumers. This makes demand response and consumer inclusion in decision making a difficult proposition. The future architecture of a power system can actually consist of a centralized grids interacting with a cluster of community level microgrids. These microgrids with built-in intelligence, local generation facilities and control mechanisms would be a better option to optimally operate the power system.

Conclusion

There is an enormous potential for setting up microgrids and they can be a value proposition for emerging economies. If a good match is made between consumer energy needs and appropriate systems, microgrids have the makings of a success story and can act as a leapfrogging technology in the energy industry of these countries. ◆

Notes

1 *Load shedding is the manual cutting off of electric power to any locality by the utility due to power shortage.*

2 *Venkataramanan, G.; Marnay, C., "A larger role for microgrids," Power and Energy Magazine, IEEE , vol.6, no.3, pp.78,82, May-June 2008.*

3 *IEA, 2011, Energy for All: Financing access for the poor http://www.iea.org/media/weowebsite/energydevelopment/weo2011_energy_for_all.pdf*

4 *http://spectrum.ieee.org/energy/the-smarter-grid/a-microgrid-that-wouldnt-quit*

5 *http://www.utsandiego.com/sponsored/2013/nov/10/sgde-repair-crews-storm/*

Dr Kumudhini Ravindra *is an author, editor and speaker, with a distinction of first PhD in Community Microgrids.*
Her email-id is kumudhini.ravindra@gmail.com