Ashden India
Renewable Energy Collective

SHAKTI
SUSTAINABLE ENERGY FOUNDATION

Briefing paper series on decentralised renewable energy for sustainable energy access

DRE-Based Micro Grids: Motivation for Developing Grid-Interactive Systems

Background

There are approximately 79 million households in India that have no access to electricity, and 74 million of those live in rural areas. These households are currently dependent on kerosene for lighting and other sources such as diesel genset for electricity for productive uses. The usual approach to serving communities without any access to electricity is to extend the central grid. However, this approach is technically and financially inefficient due to a combination of the following factors:

- Scarcity of the capital to set up new generating plants and transmission networks
- Insufficient energy demand (both current and future) to justify extension of the grid
- Logistic challenges to connecting remote areas
- Bare conductor transmission lines unsuitable for forest areas where trees leaning on power lines cause frequent supply interruptions

Decentralized renewable energy (DRE) based mini and microgrids can help provide electricity to rural households in a sustainable manner.

DRE technologies in micro grid

The easiest way to generate electricity in areas not serviced by electrical networks is with a generator that burns fossil fuels like diesel, gas, or heavy fuel oil. Diesel-based micro grids are by far the most common across the globe, mainly because of the relatively low up front capital cost, easy availability and serviceability of the diesel generator, and easy availability of diesel fuel. Reducing the reliance of remote communities on fossil fuels is driving the development of technologies designed to integrate, manage, and control renewable generation in isolated networks. This technology has successfully increased the production and integration of renewable energy into isolated power generation systems that once relied on fossil fuels alone.

Micro grids commonly use several generation resources that include (a) solar photovoltaics (PV), (b) micro hydro, and (c) biomass gasification, as well as hybrid technologies such as wind-diesel and PV-diesel.

The micro hydro-based micro grids are typically run-of-the-river type schemes where the falling water from a river or stream is diverted through a pipe into a turbine to produce electricity. Biomass gasifier systems burn biomass to produce gas that runs a generator. Solar PV systems have gained popularity mainly due to the reductions in the global market prices of PV modules. Both PV and wind systems typically use a battery bank to store the electricity for times when it is needed the most. This technical evolution in the networking technology, both for power management and end user services such as biling, load management, and remote diagnostics are enabled as a direct result of modern information and communication technologies.

Definition and categorization

The terms *mini grid* and *micro grid* refer to (relatively) small electricity networks that are used to distribute alternate or direct electric current within a village or neighbourhood. The generation source (diesel genset or DRE) is an integral part of these mini and micro grids. Such

>> Highlights

- There are many types of micro grids and they need to be categorised for purposes of planning and policy-making.
- It is essential to have specific policies, investment funds, and special mechanisms for the streamlined implementation and operation of various categories of micro grids.
- There is a critical need for clarity on the status of a micro grid post arrival of the centralised grid.
- Micro grids can complement and benefit the central grid.
- During peak demand periods, micro grids can boost the power of the central grid to make them more resilient and reliable.
- It is necessary to lay down norms and checks to ensure that micro grids are compatible with the grid and supply grid quality power.
- Climate finance can provide viability gap funding for renewable energy-based micro grids given that they typically replace diesel generators.

This briefing paper series has been conceptualised and prepared by the Ashden India Renewable Energy Collective (AIREC) with support from the Shakti Sustainable Energy Foundation. AIREC is a not-for-profit company set up by a group of India-based winners of the Ashden Awards for Sustainable Energy. Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. For more information, please visit <http://www.shaktifoundation.in>

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generation-cum-distribution solutions are mostly used in areas that are remote from national or regional grids. Mini and micro grids have been informally defined and categorised in many ways, by the size of the system, by the type of technology used, and by the area of operation (see Box 1).

It is recommended that India adopt a clear system of categorisation of decentralised electricity grids for policy purposes. A suggested categorisation, drawing on the classification for small hydro systems could be as follows:

Home system	Pico grid	Micro grid	Mini grid
150 watt (max capacity)	300 watt (max)) DC	≤1kW AC	1–100 kW AC

Issues and challenges associated with operating micro grids in the Indian context

While micro grids have proven to be a viable option for supplementing the grid supply, it is often a daunting task to design, manage, and operate remote micro grids in developing countries. Sufficient expertise is needed in the key domains of engineering, finance, management, and importantly, community engagement. There are uncertainties and questions around micro grids, particularly DRE-based micro grids. While some of these

BOX 1: Widely used definitions and categories of micro grid systems

Mini grid

A mini grid is defined as a distributing electricity network operating at less than 11 kW, which is at times (though quite seldom) connected to the central utility grid. Several documents concerning clean development mechanisms under the United Nations Framework Convention on Climate Change (UNFCCC) define mini grids for their own projects as a small-scale power system with a total power capacity not above 15 kW. Simply put, it is the sum of installed capacity of all generators connected to the mini grid, which is equal to or less than 15 kW. According to Task 11 of the PV systems programme under the International Energy Agency, a mini grid is defined as a set of electricity generators, and possibly energy storage systems, interconnected to a distribution network that supplies the entire electricity demand of a localized group of customers. In short, a mini grid is a smaller version of a grid with a backbone system of interconnected transmission lines, substations, and generating plants.

Micro grid

In most developing countries, including India, the generation capacity of a mini grid is in the sub-MW range, from as little as 1 kW to as large as a few hundred kilowatts, depending on (a) number of customers served, (b) types of services provided, and (c) type of generation technology used. These mini grids are also termed as micro or even pico grids. A micro grid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.

Pico grid

The term *pico*, particularly in the context of solar PV technology, refers to small capacity systems that can be as small as just a few watts. These systems have been made possible due to the significant developments in the last few years, the most noteworthy of which is combining the use of highly efficient lights (mostly LEDs) with far improved range of charge controllers and batteries. It is possible to provide lighting, mobile phone charging, and radio operation with just a few watts of PV power through pico grids.

DC micro grid

An alternative is to install a DC network linking DC devices to DC power supplies. Such networks have not yet become popular because of the higher electrical losses associated with transmitting a fixed amount of power as low voltage DC, rather than higher voltage AC. But with the proliferation of low power electronic devices bringing the potential for LEDs to reduce lighting loads for efficient distributed power generation, localised DC networks will likely become a preferred option for small and closely located households or shops.

AC micro grid

Another alternative is to install small AC networks that match the basic norms of the national grid, like voltage and frequency. One of the advantages of this system is that most appliances can be used and some productive applications can also be taken up for economic activities. Such systems can easily be synchronised with the national grid.

issues are intrinsic to off-grid electricity generation, others are rooted in the policy and regulatory framework of the country. Some of the uncertainties are as follows.

- **Poor load factor, inadequate and uncertain demand for power output.** It is essential to have specific policies, investment funds, and special mechanisms for the streamlined implementation and operation of a micro grid programme. A major challenge seems to be on the load side as the market for electricity is very underdeveloped and commercial demand is low in rural areas. In a vast number of villages, electricity is not linked to productive activities in the minds of villagers; to them, electricity is only used for lighting and entertainment purposes. It is thus very important to develop loads such as irrigation pumps, value added agricultural services, and refrigeration prior to investing in micro grids. Linkages and load creation are pivotal to the operational and commercial sustainability of micro grids. A small number of such loads can provide a significant and reliable revenue stream.
- **Capability of system to provide power on a 24x7 basis.** Though technically feasible, it may still not be commercially viable to design and operate a stand-alone micro grid to supply 24x7 electricity because of the high cost of generation and storage technologies. At best, a micro grid may only be able to provide power for 6 hours a day to rural consumers. Hybrid systems may have more possibilities, but there are technical and policy glitches to be overcome (as discussed in Paper #4 in this series).
- **Poor reliability of systems, particularly with regard to safety of operations and service ability.** Even though micro grids are a good option to provide reliable electricity to off-grid areas, they still face challenges due to poor load factors, unavailability of standby power during maintenance periods, and inability to maintain emergency services during maintenance periods. In most of the states, the electrical inspectorate is not familiar with micro grids. Ironically, the mushrooming number of diesel-based micro grid operators do not seek approval from the electrical inspectorate and this practice seems to extend to DRE-based micro grids also.
- **Financial viability resulting from unclear tariff-setting norms and concerns with regard to tariff collection.**
  - There is no uniform approach to setting tariffs for micro grids. The micro grid operators and users tend to follow a mutually agreeable practice of fixing the tariff within the unelectrified areas. In terms of unit price, tariffs may be very high, but may still be lower than the diesel-based tariffs and acceptable to users on a fixed payment basis.
  - The collection of payments from household customers is often cumbersome. A micro grid system could benefit from the use of load limiters or automated collection devices, but implementation has been challenging. Consumers may need to be motivated to pay by making it possible to pay in small instalments and by aligning payments to their income streams. However, arranging for door-to-door collection of payments once or twice a month, setting up a local office, or including automated collection all add to overhead costs.

The sustainability of a micro grid becomes uncertain once the central grid is extended to a village or hamlet. A possible solution is to convert such micro grids into islandable systems that can (a) feed electricity into the central grid, or (b) island themselves during shortages in the central grid. Such grid-interactive micro grids are now successfully implemented in several countries and can ensure long-term sustainability to the assets and operations while also improving local electricity service quality.

Integration/interconnection with national grid

Grid-interactive DRE systems can be a win–win for both the DRE entrepreneur who can now overcome the challenges of low demand and intermittent power supply, and for the power-starved DISCOM where the micro grid can fill in for periods of power supply interruption.

Important advantages of a micro grid with grid integration

A major advantage of a micro grid is its ability during a utility grid disturbance to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the micro grid structure. During peak load periods, a micro grid prevents utility grid failure by reducing the load in the grid. An environmental benefit of micro grids is that they use low or zero emission generators. Also, the use of both heat and electricity permitted by the close proximity of the generator to the user leads to enhanced energy efficiency.

Key disadvantages of a micro grid with grid integration

Voltage, frequency, and power quality are the three main parameters that should be considered and controlled to acceptable standards while the power and energy balance is maintained. The most limiting factors for micro grid integration are that (a) the required battery banks need a lot of space and maintenance; (b) resynchronisation with the utility grid is sometimes difficult; (c) the micro grid needs to be protected; (d) standby changes and net metering may be obstacles; and (e) interconnection standards need to be developed so as to ensure the desired level of consistency.

Ensuring that a micro grid is a 'good citizen' of the grid

The micro grid must connect to the grid without compromising the grid's reliability or protection schemes or causing other problems, consistent with the minimal standards for all connected devices. However, micro grids can offer more value to the grid than simply meeting a doing-no-harm standard. Micro grids can actually be good citizensand benefit the grid by reducing congestion and other threats to system adequacy if they are deployed as interruptible, or controlled loads that can be partially shed as necessary in response to changing grid conditions. Furthermore, the power electronics in a micro grid could also be designed so that it behaves like a constant impedance load, a modulated load, or a dispatchable load, to list a few. In addition, micro grids could provide local premium power and ancillary services, such as local voltage support, although its low voltage limits its ability to feed into the grid. If the micro grid had such features it could be considered a model citizen of the grid.

Micro grid power supply could be used as interim power supply during a power cut. In such a condition, the micro grid could provide much higher power if inverters are chosen properly at the initial stage.

Policy reform requires scaling up micro grids and fostering grid interaction

Micro grid developers depend on government policies regardless of their business model. In India, the deployment of renewable energy-based micro grids significantly increased when (a) the Electricity Act of 2003 deregulated tariffs, and (b) third party service providers were allowed in specific rural areas. These policies enabled a basic legal framework for micro grid investments. National or state governments are directly involved in the deployment and operation of micro grids wherever capital subsidies are involved. These are found to be of significance due to an improvement in the project's financial outlook.

Government decisions and policies can also lead to an impeded growth of micro grids in more ways than one. First, there is a need for clarity on the status of micro grids post-arrival of the central grid. Regulatory mechanisms to facilitate interaction of micro grids with the central grid are necessary to ensure that the micro grids provide grid quality power and do not affect the stability of the grid. Additionally, concepts such as net metering and feed-in tariffs will need to be implemented to facilitate smooth exchange of power between the micro grid and the central grid.

End users may be offered subsidies in the form of a direct monthly cash transfer. This may be a less disruptive method that ensures consumer affordability while allowing developers to maintain viability. Remunerative feed-in tariffs may be provided to the project developers to ensure viability, but project viability must factor in costs of secure and reliable maintenance contracts as well as funding of replacement of batteries and spares.

Renewable energy-based micro grids displace diesel consumption in generators and kerosene for lamps thus effectively reducing CO_2 emissions. Additional resources from climate funds can make many of these ventures more profitable and visible. Broad-basing funding away from direct government financing is necessary. A scheme where the government provides guarantees on private debt would allow state funds to multiply their effect and incentivize significant private capital investment into micro grid development. In this case, developers having trustworthy and robust cost recovery mechanisms, and low maintenance costs via community involvement may help them gain access to cheaper capital and nurture their expansion plans.

Way forward

For micro grids to be a pervasive technology like mobile phones, they would have to offer equivalent or superior services at lower costs than the grid. However, in the current scenario of highly subsidised grid power, this is unlikely. A more plausible scenario is one in which micro grids and the central grid complement each other. Some micro grids may be finally absorbed into the larger power grid. During peak demand periods, utilities can call on the micro grids for a boost of power, making the grids more resilient and reliable. If the cost of batteries comes down significantly and hybrid systems become more common, micro grids have a tremendous potential to serve as a dependable source of power, particularly for the micro and medium enterprises. The transition between grid-connected and islanded modes for distribution, generation, and high penetration of distributed generation needs to be investigated thoroughly. Given that reliability and safety are key, performance evaluation of frequency and voltage under various operational modes would be necessary. Ultimately, micro grid systems need to transform to intelligent, robust energy delivery systems by providing significant reliability and security benefits to the people directly and also to the modern grids that they are connected to.