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Microgrids: Challenges and Possibility in India

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Abstract— *Microgrids are now emerging from lab benches and pilot demonstration sites into commercial markets, driven by technological improvements, falling costs, a proven track record, and growing recognition of their benefits. They are being used to improve reliability and resilience of electrical grids, to manage the addition of distributed clean energy resources like wind and solar photovoltaic (PV) generation to reduce fossil fuel emissions, and to provide electricity in areas not served by centralized electrical infrastructure. This review article (1) explains what a microgrid is, and (2) provides a multi-disciplinary portrait of today's microgrid drivers, real-world applications, challenges, and future prospects. This paper provides an overview of the MicroGrid paradigm. This includes the basic architecture, control and protection and energy management.*

Keywords— microgrid, basic structure, microsource controller, real-world applications, challenges in India.

I. INTRODUCTION

The MicroGrid concept assumes a cluster of loads and micro-sources operating as a single controllable system that provides both power and heat to its local area. This concept provides a new paradigm for defining the operation of distributed generation. To the utility the Micro-Grid can be thought of as a controlled cell of the power system. For example this cell could be controlled as a single dispatchable load, which can respond in seconds to meet the needs of the transmission system. To the customer the Micro-Grid can be designed to meet their special needs; such as, enhance local reliability, reduce feeder losses, support local voltages, provide increased efficiency through use waste heat, voltage sag correction or provide uninterruptible power supply functions to name a few.

II. BASIC STRUCTURE

The microsources of special interest for MicroGrids are small (<100-kW) units with power electronic interfaces. These sources, (typically microturbines, PV panels, and fuel cells) are placed at customers sites. They are low cost, low voltage and have high reliable with few emissions. Power electronics provide the control and flexibility required by the MicroGrid concept. Correctly designed power electronics and controls insure that the MicroGrid can meet its customers as well as the utility's needs. The above characteristics can be achieved using system architecture with three critical components:

- Local microsource controllers
- System optimizer
- Distributed protection

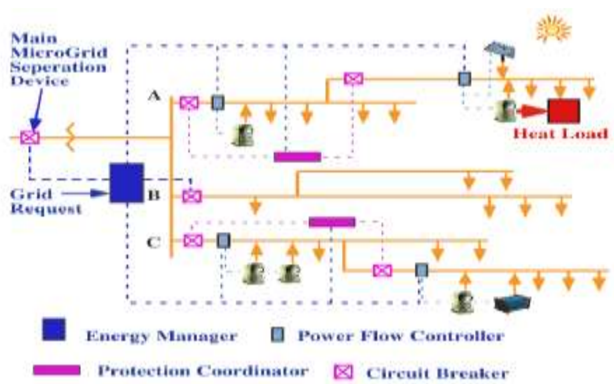

FIG. 1: Microgrid: Basic stucture

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Figure 1 illiterate the basic Microgrid architecture. In this example the electrical system is assumed to be radial with three feeders A, B and C and a collection of loads. The radial system is connected to the distribution system through a separation device, usually a static switch. The feeder voltages at the loads are usually 480 volts or less. Feeder A indicates the presents of several microsources with one providing both power and heat. Each feeder has circuit breakers and power flow controllers. Consider the power flow controller near the heat load in feeder A. This controller regulates feeder power flow at a level prescribed by the Energy Manger. As loads downstream change the local microsource increase or decreases their power output to hold the power flow constant. In this figure feeders A and C are assumed to have critical loads and include microsource, while feed B is assumed to have non-critical loads which can be shed when necessary. For example when there are power quality problems on the distribution system the Microgrid can island by using the separation device shown in the figure. The non-critical feeder can also be dropped using the breaker at B.

III. MICROSOURCE CONTROLLER

Microsource controller is an important component of the Microgrid infrastructure. This controller responds in milliseconds and uses local information to control the microsource during all events. A key element is that communications among microsources are unnecessary for basic operation. Each inverter is able to respond to load changes in a predetermined manner without communication of data from other sources or locations, which enables plug and play capabilities. Plug and play implies that a microsource can be added to the Microgrid without changes to the control and protection of units that are already part of the system. The basic inputs to this controller are steady state set points for output power, P, and local bus voltage, V.

IV. WHY DO MICROGRIDS MATTER?

A microgrid is a scaled-down version of the centralized power system. It can generate, distribute, and control power in a campus setting or a small community.

- They're reliable and flexible: Microgrids are designed to provide uninterrupted, 24/7 power and to balance load demands for an organization with changing power needs.
- They're resilient: Because Microgrids aren't dependent on the traditional grid, their stability in bad weather is important for mission-critical structures such as hospitals and military bases.
- They're more secure: The microgrid's distributed generation (power is generated locally rather than transmitted from one central utility source) and smaller size make microgrids easier to keep safe — both physically and, given the right control system, from cyber threats.
- They can save money: Using sophisticated software, operators can optimize power usage based on demand, utility prices, and other factors.
- They store and incorporate renewable energy: This can save money and reduce carbon-dioxide emissions, as often required by government regulations.

V. MICROGRIDS IN INDIA

India is one of the fastest-growing economies in the world, and it is home to approximately 18% of the global population, with the majority living in rural areas. The country has the fourth highest rate of energy consumption in the world, and it has been working on its power grid system to meet the ever-increasing demand for energy. However, India faces an uphill task of bridging the demand-supply gap. A large percentage of the Indian population (a staggering 237 million people) has either no access to electricity or unreliable access to power. In fact, most households in rural areas have no electricity despite being connected to the grid due to the shortage of power. India's US$11-billion rural electrification program, called Deen Dayal Upadhyaya Gram Jyoti Yojna, includes an objective to deliver power to 18,452 un-electrified villages by 2018. Of these, 14,204 can be served by grid extensions, and the remaining 3,449 villages require off-grid power. While work on the grid-extension aspect is proceeding ahead of schedule (with more than 51% of villages already connected), progress on the off-grid target has been very slow so far (only roughly 20%). The last decade has seen substantial activity in the deployment of ac microgrids, which are small, isolated power systems using local energy resources. The thrust has been twofold: for household consumption and for enhancement of economic

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activity. The country has also seen the emergence of industrial microgrids that use solar PV, phasing out the use of fossil fuels. The Indian government has been working on policies to address the standardization of practices that would enable wider microgrid deployment and the eventual integration of microgrids with the main grid. Because most microgrids in existence or being planned are small, isolated systems, off-grid systems, and isolated microgrids are synonymous in the Indian context.

VI. CHALLENGES IN INDIA

Microgrids in India are characterized by the fact that they are typically in nonurban, often remote areas. This makes it difficult to carry out monitoring, repair, and maintenance work in case of failures. The situation would be mitigated by research in three important areas:

- understanding the causes for degradation of PV modules
- power-electronic interfaces with well-defined and gradual failure modes
- mechanisms to remotely monitor and test interfaces and their controllers.

As the government favors solar PV-based off-grid/ microgrid power sources, it is important to study and understand the degradation of PV modules. The energy yield from solar PV sources depends on the irradiation and the local temperature, while the performance ratio depends on the site and technology adopted. These conditions vary widely throughout the country, which is classified as having five different climatic zones. This leads to variation in the performance of the modules, depending on where they are installed. Therefore, causes for the degradation require in-depth analysis to provide solutions for its minimization.

Power-electronic interfaces with well-defined failure modes should be able to operate with degraded specifications for extended periods of time, until maintenance and repairs can be effected. Ideally, these should be modular, and it should be possible to train local people in their regular maintenance, basic repairs, and module swapping. This would ensure that the failure of a part of the energy conversion system does not result in the failure of the entire system.

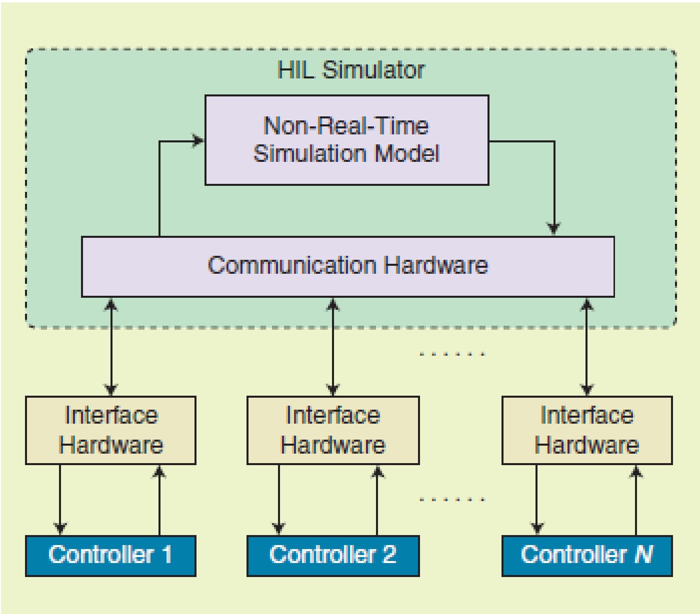

FIG. 2: HIL testing of distributed controllers

Mechanisms to remotely monitor and test power-electronic interfaces and controllers can benefit from research in distributed hardware-in-loop (HIL) testing. Figure 3 shows a scenario of HIL testing of distributed controllers. In this scenario, the HIL simulator is located at a central location and has a detailed model of the entire microgrid. The distributed controllers connect to the central simulator via communication links. The simulation progresses one step at a time by the alternate freezing and running

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of the controllers and the simulator. A critical issue in this distributed simulation scenario is the synchronization between the HIL simulator and the distributed controllers. Scenarios such as this would permit the operation and testing of controllers in interconnected microgrids.

VII. CASE STUDY: MICROGRIDS IN DHARNAI VILLAGE IN BIHAR

The rural electrification microgrid projectis based in Dharnai village in the state of Bihar, India. This part of the country is usually dry and hot. Dharnai village is not connected to the main electricity grid. The neighboring villages have unreliable grid power and poor quality. Electricity from the state utility costs about 3/kWh. However, the villagers are paying 12–14/kWh of electricity consumed from the microgrids. The microgrid consist of solar PV systems that supply electricity to households in Dharnai village on a sustainable yet affordable basis. The project currently uses roughly 280 solar panels to generate more than 100 kWp of electricity to power more than 400 households. A hybrid system (consisting of solar, biomass, and wind energy) has been planned for the future. The developer (private) offers two packages to the consumers:

- The basic package includes a charging point and one light connection: a total of 18 W per household.
- The other package includes a mobile charging point and three lighting points, with a total of 30 W. Residents opting for television or fan connections would use this package.

The microgrid also includes ten solar-powered water pumps and 60 solar street lights. The financially sustainable model of this project may be replicated by the government for electrification.

VIII. CONCLUSION

Microgrids are the future of energy management. The traditional power grid provides reliable power most of the time. But when natural disasters or security breaches threaten the grid, the ensuing blackouts can be catastrophic and costly. That's why organizations and utilities are working together to build resilient, flexible power systems called microgrids. Operating either as part of the traditional grid or independently (or both), Microgrids are revolutionizing the way we manage our energy resources. In India, people in remote areas do not have consistent access to electricity. The government had started the process of electric installation in rural areas long before by promoting renewable energy sources and locally available resources. On one hand, people in semi urban and rural areas suffer from lack of power. On the other hand, for people in urban areas, the issue is one of reliable, high quality power. Due to the vast geographical diversity and varied customer priorities and requirements, the concept of Microgrids in India has a broader and deeper role to play to bridge the gap and achieve the multiple targets of achieving equitable, sustainable, and rapid economic growth.

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