# EFFECTIVE STANDALONE MICROGRID

*A Project report submitted in partial fulfilment*

*of the requirements for the degree of B. Tech in Electrical Engineering*

**Bachelor of Technology**

**In**

**ELETRICAL ENGINEERING**

*By*


**AMIT KANDAR (EE2018/053)**

**DEBJIT MONDAL(EE2018/035)**

**SHIVAM KUNDU RAY(EE2019/L02)**

**ANKIT SAHA (EE2018/040)**

*Under the supervision of*

Asst professor –NIJAM UDDIN MOLLA

Department of Electrical Engineering


श्रमम् बिना न किमपि साध्यम्


*Department of Electrical Engineering*

**RCC INSTITUTE OF INFORMATION TECHNOLOGY**

CANAL SOUTH ROAD, BELIAGHATA, KOLKATA – 700015, WEST BENGAL

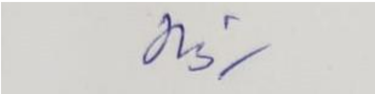
Maulana Abul Kalam Azad University of Technology (MAKAUT)


2022

## *CERTIFICATE*

### To whom it may concern

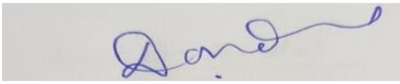
This is to certify that the project work entitled(**<u>EFFECTIVE STANDALONE MICRO GRID)</u>** is the bona fide work carried out by **AMIT KANDAR(11701618064), DEBJIT MONDAL(11701618048), SHIVAM KUNDU RAY(11701619053) ANKIT SAHA(11701618059)** , a student of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2021-22, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and this project has not submitted previously for the award of any other degree, diploma and fellowship.



**Signature of the Guide**

**Name:** **NIJAM UDDIN MOLLA**

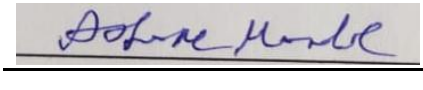
**Designation: Assistant Professor**



**Signature of the HOD, EE**

**Name:** **DEBASISH MONDAL**

**Designation: Professor**



**Signature of the External Examiner**

**Name:** **ASHOKE MONDAL**

**Designation: HOD, ECE**

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Amit Kandar
Debjit Mandal
Ankit Saha
Shivam Kundu Ray
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**Signature of the Students**

**Place:**

**Date:**

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# ABSTRACT

*In these days disruption of power supply is very common issue faced by majority in which any fault in feeder or main distribution lines lead to a complete blackout due to which whole system will be out of order and functionality of industries will be stopped.*

*But smart grid system has capability to secure the system on the spot by handling emergencies because they possess the ability of automatic rerouting in case of any fault current . Smart Grids are not only providing the link between consumers and utilities moreover they enable users to handle their electricity usage systematically like we use online banking from anywhere any time.*

*Management of electricity in well-organized matter will clearly lead to cost reduction. One of the interesting application is smart meters. With the help of smart meters we need not to wait a whole month to get electricity bill rather we can see reading and receive bill daily online which will obviously save money for consumers and save electricity or power for whole country which will provide support in economical stability of the country.*

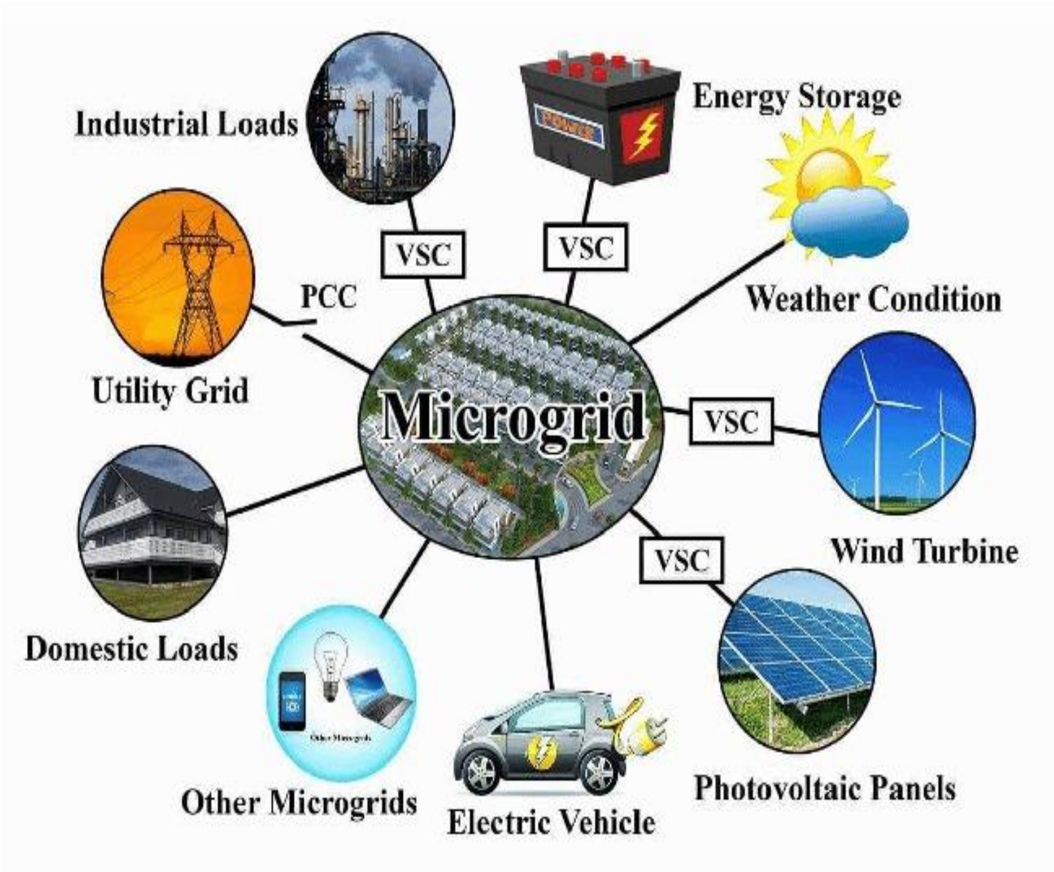
*Coming toward the precautions as this system has wide range of technical data and equipment along with automation equipments and protocols, so most important thing will be to ensure whether the system is properly installed because, if there will be no loop holes in deployment of this technology, smart grids on global level will bring revolution in power sector same as internet did transformation in the World of IT*

## Applications of a Smart Grid System

- *They improve the adeptness of transmission lines*
- *Quick recovery after any sudden breakage/disturbance in lines and feeders*
- *Cost Reduction*
- *Reduction of peak demand*
- *They possess the ability to be integrated with renewable energy sources on a large level which leads to sharing of load and reduction of load on large scale*

# INTRODUCTION

**To the era of microgrid**



## Historical development of the electricity grid

The first alternating current power grid system was installed in 1886 in Great Barrington, Massachusetts.At that time, the grid was a centralized unidirectional system of electric power transmission, electricity distribution, and demand-driven control.

In the 20th century, local grids grew over time and were eventually interconnected for economic and reliability reasons. By the 1960s, the electric grids of developed countries had become very large, mature, and highly interconnected, with thousands of 'central' generation power stations delivering power to major load centres via high capacity power lines which were then branched and divided to provide power to smaller industrial and domestic users over the entire supply area. The topology of the 1960s grid was a result of the strong economies of scale: large coal-, gas- and oil-fired power stations in the 1 GW (1000 MW) to 3 GW scale are still found to be cost-effective, due to efficiency-boosting features that can be cost-effective only when the stations become very large.

Power stations were located strategically to be close to fossil fuel reserves (either the mines or wells themselves or else close to rail, road, or port supply lines). Siting of hydroelectric dams in mountain areas also strongly influenced the structure of the emerging grid. Nuclear power plants were sited for the availability of cooling water. Finally, fossil fuel-fired power stations were initially very polluting and were sited as far as economically possible from population centres once electricity distribution networks permitted it. By the late 1960s, the electricity grid reached the overwhelming majority of the population of developed countries, with only outlying regional areas remaining 'off-grid'.

Metering of electricity consumption was necessary on a per-user basis in order to allow appropriate billing according to the (highly variable) level of consumption of different users. Because of limited data collection and processing capability during the period of growth of the grid, fixed-tariff arrangements were commonly put in place, as well as dual-tariff arrangements where night-time power was charged at a lower rate than daytime power. The motivation for dual-tariff arrangements was the lower night-time demand. Dual tariffs made possible the use of low-cost night-time electrical power in applications such as the maintaining of 'heat banks' which served to 'smooth out' the daily demand, and reduce the number of turbines that needed to be turned off overnight, thereby improving the utilisation and profitability of the generation and transmission facilities. The metering capabilities of the 1960s grid meant technological limitations on the degree to which price signals could be propagated through the system.

From the 1970s to the 1990s, growing demand led to increasing numbers of power stations. In some areas, the supply of electricity, especially at peak times, could not keep up with this demand, resulting in poor power quality including blackouts, power cuts, and brownouts. Increasingly, electricity was depended on for industry, heating, communication, lighting, and entertainment, and consumers demanded ever-higher levels of reliability.

Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air-conditioning led to daily peaks in demand that were met by an array of 'peaking power generators' that would only be turned on for short periods each day. The relatively low utilisation of these peaking generators (commonly, gas turbines were used due to their relatively lower capital cost and faster start-up times), together with the necessary redundancy in the electricity grid, resulting in high costs to the electricity companies, which were passed on in the form of increased tariffs.

In the 21st century, some developing countries like China, India, and Brazil were seen as pioneers of smart grid deployment

## Modernization opportunities

Since the early 21st century, opportunities to take advantage of improvements in electronic communication technology to resolve the limitations and costs of the electrical grid have become apparent. Technological limitations on metering no longer force peak power prices to be averaged out and passed on to all consumers equally. In parallel, growing concerns over environmental damage from fossil-fired power stations have led to a desire to use large amounts of renewable energy. Dominant forms such as wind power and solar power are highly variable, and so the need for more sophisticated control systems became apparent, to facilitate the connection of sources to the otherwise highly controllable grid.[9] Power from photovoltaic cells (and to lesser extent wind turbines) has also, significantly, called into question the imperative for large, centralised power stations. The rapidly falling costs point to a major change from the centralised grid topology to one that is highly distributed, with power being both generated and consumed right at the limits of the grid. Finally, growing concern over terrorist attacks in some countries has led to calls for a more robust energy grid that is less dependent on centralised power stations that were perceived to be potential attack targets.

## DEFINIATION OF MICROGRID

The United States Department of Energy Microgrid Exchange Group[7] defines a microgrid as a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both connected or island-mode.

A EU research project describes a microgrid as comprising Low-Voltage (LV) distribution systems with distributed energy resources (DERs) (microturbines, fuel cells, photovoltaics (PV), etc.), storage devices (batteries, flywheels) energy storage system and flexible loads. Such systems can operate either connected or disconnected from the main grid. The operation of microsources in the network can provide benefits to the overall system performance, if managed and coordinated efficiently.

Electropedia defines a microgrid as a group of interconnected loads and distributed energy resources with defined electrical boundaries, which form a local electric power system at distribution voltage levels, meaning both low and medium voltage up to 35 kV. This cluster of associated consumer and producer nodes acts as a single controllable entity and is able to operate in either grid-connected or island mode.

Now according to dictionary, **microgrid** is a decentralized group of electricity sources and loads that normally operates, connected to and synchronous with the traditional wide area synchronous grid (macrogrid), but is able to disconnect from the interconnected grid and to function autonomously in "island mode" as technical or economic conditions dictate. In this way, microgrids improve the security of supply within the microgrid cell, and can supply emergency power, changing between island and connected modes. Another use case is the off-grid application, it is called an autonomous, stand-alone or isolated microgrid. These microgrids are best served by local energy sources where power transmission and distribution from a major centralized energy source is too far and costly to execute. They offer an option for rural electrification in remote areas and on smaller geographical islands. As a controllable entity, a microgrid can effectively integrate various sources of distributed generation (DG), especially renewable energy sources (RES).

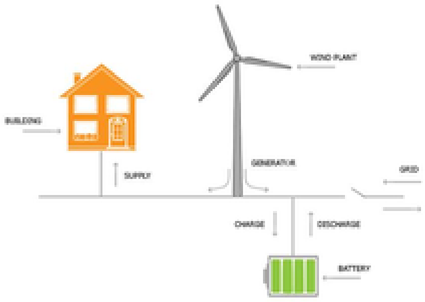
Control and protection are difficulties to microgrids, as all ancillary services for system stabilization must be generated within the microgrid and low short-circuit levels can be challenging for selective operation of the protection systems. An important feature is also to provide multiple useful energy needs, such as heating and cooling besides electricity, since this allows energy carrier substitution and increased energy efficiency due to waste heat utilization for heating, domestic hot water, and cooling purposes (cross sectoral energy usage).

# BRIEF INFORMATION

## OF MICROGRID

The Solar Settlement, a sustainable housing community project in Freiburg, Germany.

## Types of microgrids



A typical scheme of an electric based microgrid with renewable energy resources in grid-connected mode

### Campus environment/institutional microgrids

The focus of campus microgrids is aggregating existing on-site generation to support multiple loads located in a tight geographical area where an owner can easily manage them.

### Community microgrids

Community microgrids can serve thousands of customers and support the penetration of local energy (electricity, heating, and cooling). In a community microgrid, some houses may have some renewable sources that can supply their demand as well as that of their neighbors within the same community. The community microgrid may also have a centralized or several distributed energy storages. Such microgrids can be in the form of an ac and dc microgrid coupled together through a bi-directional power electronic converter.

### Remote off-grid microgrids

These microgrids never connect to the microgrid and instead operate in an island mode at all times because of economic issues or geographical position. Typically, an "off-grid" microgrid is built in areas that are far distant from any transmission and distribution infrastructure and, therefore, have no connection to the utility grid. Studies have demonstrated that operating a remote area or islands' off-grid microgrids, that are dominated by renewable sources, will reduce the levelized cost of electricity production over the life of such microgrid projects.

Large remote areas may be supplied by several independent microgrids, each with a different owner (operator). Although such microgrids are traditionally designed to be energy self-sufficient, intermittent renewable sources and their unexpected and sharp variations can cause unexpected power shortfall or excessive generation in those microgrids. This will immediately cause unacceptable voltage or frequency deviation in the microgrids. To remedy such situations, it is possible to interconnect such microgrids provisionally to a suitable neighboring microgrid to exchange power and improve the voltage and frequency deviations. This can be achieved through a power electronics-based switch after a proper synchronization[1] or a back to back connection of two power electronic converters[1] and after confirming the stability of the new system. The determination of a need to interconnect neighboring microgrids and finding the suitable microgrid to couple with can be achieved through optimization or decision making approaches.

**Military base microgrids**

These microgrids are being actively deployed with focus on both physical and cyber security for military facilities in order to assure reliable power without relying on the microgrid.

**Commercial and industrial (C&I) microgrids**

These types of microgrids are maturing quickly in North America and eastern Asia; however, the lack of well-known standards for these types of microgrids limits them globally. Main reasons for the installation of an industrial microgrid are power supply security and its reliability. There are many manufacturing processes in which an interruption of the power supply may cause high revenue losses and long start-up time. Industrial microgrids can be designed to supply circular economy (near-)zero-emission industrial processes, and can integrate combined heat and power (CHP) generation, being fed by both renewable sources and waste processing; energy storage can be additionally used to optimize the operations of these sub-systems.

## Topologies of microgrids

Architectures are needed to manage the flow of energy from different types of sources into the electrical grid. Thus, the microgrid can be classified into three topologies.

### AC microgrid

Power sources with AC output are interfaced to AC bus through AC/AC converter which will transform the AC variable frequency and voltage to AC waveform with another frequency at another voltage. Whilst power sources with DC output use DC/AC converters for the connection to the AC bus.

### DC microgrid

In DC microgrid topology, power sources with DC output are connected to DC bus directly or by DC/DC converters. On the other hand, power sources with AC output are connected to the DC bus through AC/DC converter.

### Hybrid microgrid

The hybrid microgrid has topology for both power source AC and DC output. In addition, AC and DC buses are connected to each other through a bidirectional converter, allowing power to flow in both directions between the two buses.

## Basic components in microgrids

### Local generation

A microgrid presents various types of generation sources that feed electricity, heating, and cooling to the user. These sources are divided into two major groups – thermal energy sources (e.g,. natural gas or biogas generators or micro combined heat and power) and renewable generation sources (e.g. wind turbines and solar).

### Consumption

In a microgrid, consumption simply refers to elements that consume electricity, heat, and cooling, which range from single devices to the lighting and heating systems of buildings, commercial centers, etc. In the case of controllable loads, electricity consumption can be modified according to the demands of the network.

### Energy storage

In microgrid, energy storage is able to perform multiple functions, such as ensuring power quality, including frequency and voltage regulation, smoothing the output of renewable energy sources, providing backup power for the system and playing a crucial role in cost optimization. It includes all of chemical, electrical, pressure, gravitational, flywheel, and heat storage technologies. When multiple energy storages with various capacities are available in a microgrid, it is preferred to coordinate their charging and discharging such that a smaller energy storage does not discharge faster than those with larger capacities. Likewise, it is preferred a smaller one does not get fully charged before those with larger capacities. This can be achieved under a coordinated control of energy storages based on their state of charge.[27] If multiple energy storage systems (possibly working on different technologies) are used and they are controlled by a unique supervising unit (an energy management system - EMS), a hierarchical control based on a master/slaves architecture can ensure best operations, particularly in the islanded mode.[25]

### Point of common coupling (PCC)

This is the point in the electric circuit where a microgrid is connected to a main grid.[28] Microgrids that do not have a PCC are called isolated microgrids which are usually present in remote sites (e.g., remote communities or remote industrial sites) where an interconnection with the main grid is not feasible due to either technical or economic constraints.

## Advantages and challenges of microgrids

### Advantages

A microgrid is capable of operating in grid-connected and stand-alone modes and of handling the transition between the two. In the grid-connected mode, ancillary services can be provided by trading activity between the microgrid and the main grid. Other possible revenue streams exist. In the islanded mode, the real and reactive power generated within the microgrid, including that provided by the energy storage system, should be in balance with the demand of local loads. Microgrids offer an option to balance the need to reduce carbon emissions with continuing to provide reliable electric energy in periods of time when renewable sources of power are not available. Microgrids also offer the security of being hardened from severe weather and natural disasters by not having large assets and miles of above-ground wires and other electric infrastructure that need to be maintained or repaired following such events

A microgrid may transition between these two modes because of scheduled maintenance, degraded power quality or a shortage in the host grid, faults in the local grid, or for economical reasons. By means of modifying energy flow through microgrid components, microgrids facilitate the integration of renewable energy, such as photovoltaic, wind and fuel cell generations, without requiring re-design of the national distribution system.Modern optimization methods can also be incorporated into the microgrid energy management system to improve efficiency, economics, and resiliency.

### Challenges

Microgrids, and the integration of DER units in general, introduce a number of operational challenges that need to be addressed in the design of control and protection systems, in order to ensure that the present levels of reliability are not significantly affected, and the potential benefits of Distributed Generation (DG) units are fully harnessed. Some of these challenges arise from assumptions typically applied to conventional distribution systems that are no longer valid, while others are the result of stability issues formerly observed only at a transmission system level. The most relevant challenges in microgrid protection and control include:

Bidirectional power flows: The presence of distributed generation (DG) units in the network at low voltage levels can cause reverse power flows that may lead to complications in protection coordination, undesirable power flow patterns, fault current distribution, and voltage control.

Stability issues: Interactions between control system of DG units may create local oscillations, requiring a thorough small-disturbance stability analysis. Moreover, transition activities between the grid-connected and islanding (stand-alone) modes of operation in a microgrid can create transient instability. Recent studies have shown that direct-current (DC) microgrid interface can result in a significantly simpler control structure, more energy efficient distribution and higher current carrying capacity for the same line ratings.

Modeling: Many characteristics of traditional schemes such as the prevalence of three-phase balanced conditions, primarily inductive transmission lines, and constant-power loads, do not necessarily hold true for microgrids, and consequently, models need to be revised.

Low inertia: Microgrids exhibit a low-inertia characteristic that makes them different to bulk power systems, where a large number of synchronous generators ensures a relatively large inertia. This phenomenon is more evident if there is a significant proportion of power electronic-interfaced DG units in the microgrid. The low inertia in the system can lead to severe frequency deviations in island mode operation if a proper control mechanism is not implemented. Synchronous generators run at the same frequency as the grid, thus providing a natural damping effect on sudden frequency variations. Synchronverters are inverters which mimic synchronous generators to provide frequency control. Other options include controlling battery energy storage or a flywheel to balance the frequency.

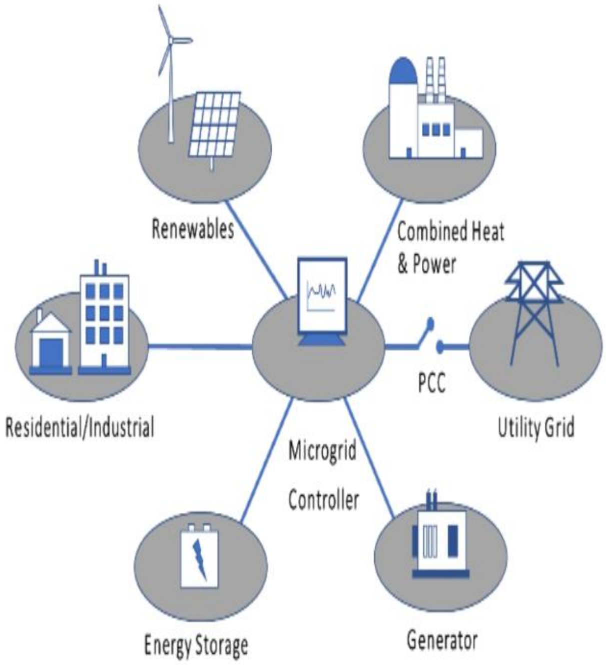
Uncertainty: The operation of microgrids involves addressing much uncertainty, which is something the economical and reliable operation of microgrids relies on. Load profile and weather are two uncertainties that make this coordination more challenging in isolated microgrids, where the critical demand-supply balance and typically higher component failure rates require solving a strongly coupled problem over an extended time horizon. This uncertainty is higher than those in bulk power systems, due to the reduced number of loads and highly correlated variations of available energy resources (the averaging effect is much more limited).

**Modelling tools**

To plan and install microgrids correctly, engineering modelling is needed. Multiple simulation tools and optimization tools exist to model the economic and electric effects of microgrids. A widely used economic optimization tool is the Distributed Energy Resources Customer Adoption Model (DER-CAM) from Lawrence Berkeley National Laboratory. Another is Homer Energy, originally designed by the National Renewable Energy Laboratory. There are also some power flow and electrical design tools guiding microgrid developers. The Pacific Northwest National Laboratory designed the publicly available GridLAB-D tool and the Electric Power Research Institute (EPRI) designed OpenDSS. A European tool that can be used for electrical, cooling, heating, and process heat demand simulation is EnergyPLAN from Aalborg University in Denmark. The open source grid planning tool OnSSET has been deployed to investigate microgrids using a three-tier analysis beginning with settlement archetypes (case-studied using Bolivia).

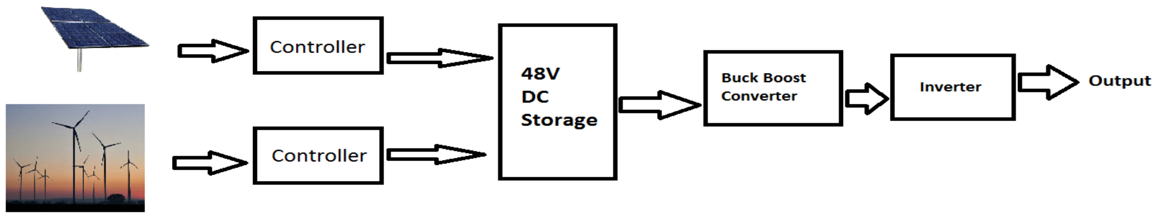
# KEY MICROGRID COMPONENTS

- **A microgrid has five key components:**
  - Energy sources (generators and storage)
  - Energy sinks (loads)
  - A means for connecting to/disconnecting from a larger power system
  - Means for controlling ("regulating") the microgrid
  - Appropriate safety-assurance systems ("protection")
- **The energy sources must have the ability to provide certain critical functions that are usually provided by the larger grid, such as:**
  - "Black start"—starting up the microgrid by themselves, after a full outage/blackout
  - Surge capability—some loads when they turn on draw big pulses of power, and the microgrid sources have to be able to supply those
  - Voltage and frequency regulation—keeping the voltage at your outlets within specified ranges (i.e., "grid forming" versus "grid following")



# CONSTRUCTION OF

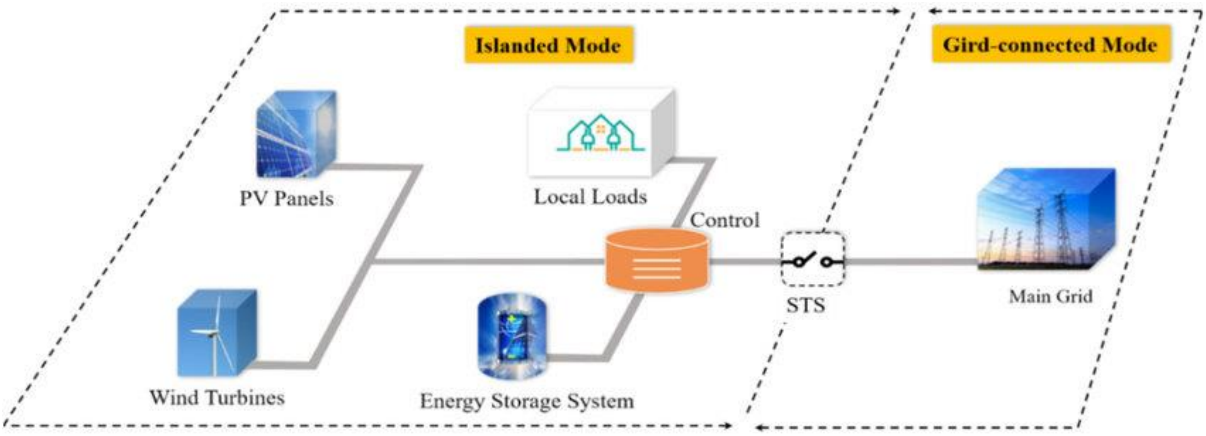
# MICROGRID




The basic construction of the Microgrid having 2 generating unit, which might be Solar or Wind generation. The power generated from particular power source, the source been supply to controller. A charge controller is **used to keep the battery from overcharging by regulating the voltage and current coming from the solar panel to the battery**. It is programmed at 15-A/200-W unit and uses MPPT (maximum power point tracking) to accelerate solar charging of the battery up to 30% per day. After that the charge has to store inside the battery. Then after the charge is passed to Buck boost or boost converter. **The boost converter is designed to step up a fluctuating solar panel voltage to a higher constant DC voltage**. It uses voltage feedback to keep the output voltage constant.

Finally the charge been send through inverter, where the current is converted to DC supply to AC supply and then after to the consumer.

# MICROGRID CONTROL




In regards to the architecture of microgrid control, or any control problem, there are two different approaches that can be identified: centralized and decentralized. A fully centralized control relies on a large amount of information transmittance between involving units before a decision is made at a single point. Implementation is difficult since interconnected power systems usually cover extended geographic locations and involve an enormous number of units. On the other hand, in a fully decentralized control, each unit is controlled by its local controller without knowing the situation of others. A compromise between those two extreme control schemes can be achieved by means of a hierarchical control scheme consisting of three control levels: primary, secondary, and tertiary.

**Primary control**

The primary control is designed to satisfy the following requirements:

- To stabilize the voltage and frequency
- To offer plug and play capability for DERs and properly share the active and reactive power among them, preferably, without any communication links
- To mitigate circulating currents that can cause over-current phenomenon in the power electronic devices

The primary control provides the setpoints for a lower controller which are the voltage and current control loops of DERs. These inner control loops are commonly referred to as zero-level control.

**Secondary control**

Secondary control has typically seconds to minutes sampling time (i.e. slower than the previous one) which justifies the decoupled dynamics of the primary and the secondary control loops and facilitates their individual designs. The setpoint of primary control is given by secondary control in which, as a centralized controller, it restores the microgrid voltage and frequency and compensates for the deviations caused by variations of loads or renewable sources. The secondary control can also be designed to satisfy the power quality requirements, e.g., voltage balancing at critical buses.

**Tertiary control**

Tertiary control is the last (and the slowest) control level, which considers economical concerns in the optimal operation of the microgrid (sampling time is from minutes to hours), and manages the power flow between microgrid and main grid. This level often involves the prediction of weather, grid tariff, and loads in the next hours or day to design a generator dispatch plan that achieves economic savings. More advanced techniques can also provide end to end control of a microgrid using machine learning techniques such as deep reinforcement learning.

In case of emergencies such as blackouts, tertiary control can manage a group of interconnected microgrids to form what is called "microgrid clustering", acting as a virtual power plant to continue supplying critical loads. During these situations the central controller should select one of the microgrids to be the slack (i.e. master) and the rest as PV and load buses according to a predefined algorithm and the existing conditions of the system (i.e. demand and generation). In this case, the control should be real time or at least at a high sampling rate.

**IEEE 2030.7**

A less utility-influenced controller framework is that from the Institute of Electrical and Electronics Engineers, the IEEE 2030.7. The concept relies on 4 blocks: a) Device level control (e.g. voltage and frequency control), b) Local area control (e.g. data communication), c) Supervisory (software) control (e.g. forward looking dispatch optimization of generation and load resources), and d) Grid layers (e.g. communication with utility).

**Elementary control**

A wide variety of complex control algorithms exist, making it difficult for small microgrids and residential distributed energy resource (DER) users to implement energy management and control systems. Communication upgrades and data information systems can be expensive. Some projects try to simplify and reduce the expense of control via off-the-shelf products (e.g. using a Raspberry Pi).

# REAL WORLD

# IMPLEMENTATION

### *Hajjah and Lahj, Yemen*

The UNDP project "Enhanced Rural Resilience in Yemen" (ERRY) uses community-owned solar microgrids. It cuts energy costs to just 2 cents per hour (whereas diesel-generated electricity costs 42 cents per hour). It won the Ashden Awards for Humanitarian Energy in 2020.

### *Île d'Yeu*

A two year pilot program, called Harmon’Yeu, was initiated in the Spring of 2020 to interconnect 23 houses in the Ker Pissot neighborhood and surrounding areas with a microgrid that was automated as a smart grid with software from Engie. Sixty-four solar panels with a peak capacity of 23.7 kW were installed on five houses and a battery with a storage capacity of 15 kWh was installed on one house. Six houses store excess solar energy in their hot water heaters. A dynamic system apportions the energy provided by the solar panels and stored in the battery and hot water heaters to the system of 23 houses. The smart grid software dynamically updates energy supply and demand in 5 minute intervals, deciding whether to pull energy from the battery or from the panels and when to store it in the hot water heaters. This pilot program was the first such project in France.

## *Les Anglais, Haiti*

A wirelessly managed microgrid is deployed in rural Les Anglais, Haiti. The system consists of a three-tiered architecture with a cloud-based monitoring and control service, a local embedded gateway infrastructure and a mesh network of wireless smart meters deployed at fifty-two buildings.

Non-technical loss (NTL) represents a major challenge when providing reliable electrical service in developing countries, where it often accounts for 11-15% of total generation capacity.An extensive data-driven simulation on seventy-two days of wireless meter data from a 430-home microgrid deployed in Les Anglais investigated how to distinguish NTL from the total power losses, aiding in energy theft detection.

## *Mpeketoni, Kenya*

The Mpeketoni Electricity Project, a community-based diesel-powered micro-grid system, was set up in rural Kenya near Mpeketoni. Due to the installment of these microgrids, Mpeketoni has seen a large growth in its infrastructure. Such growth includes increased productivity per worker, at values of 100% to 200%, and an income level increase of 20–70% depending on the product.

## *Stone Edge Farm Winery*

A micro-turbine, fuel-cell, multiple battery, hydrogen electrolyzer, and PV enabled winery in Sonoma, California.

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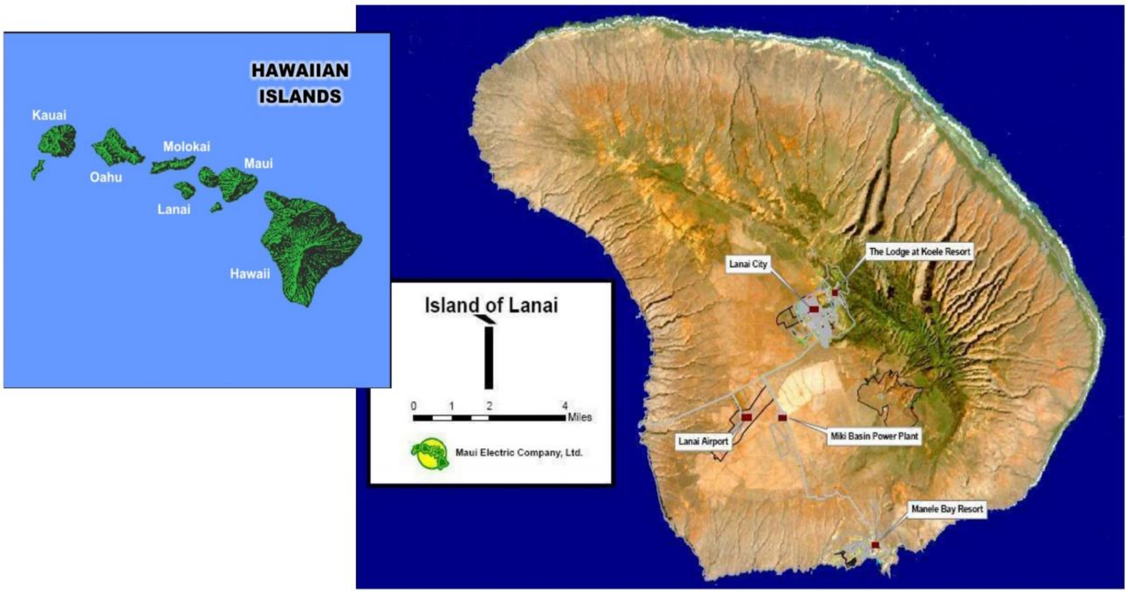
# ISLAND OF LANAI EXAMPLE

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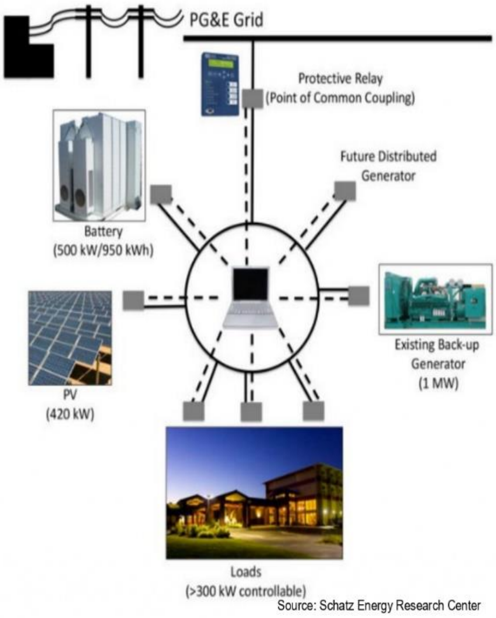
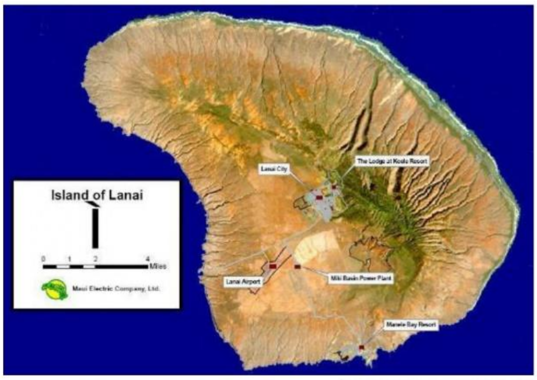
# BLUE LAKE RANCHERIA MICROGRID EXAMPLE

- Functioning example of a secure, reliable, low-carbon microgrid for a Native American tribe
- Has single point of common coupling between the microgrid and the main utility grid for seamless islanded if main utility grid losses power
- Can optimally dispatch battery power under normal conditions by using energy load and PV availability forecasting and rate schedule
- Increases use of local renewable energy, thus reducing CO2 emissions
- Designated American Red Cross evacuation center

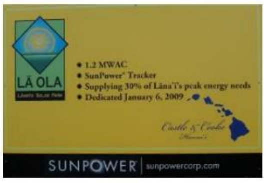


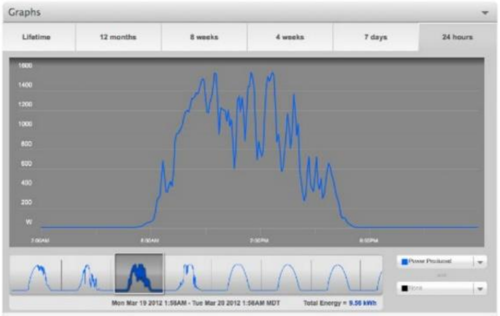

# ISLAND OF LANAI EXAMPLE




(6) 1.0 MW EMD Diesel Generators
(2) 2.2 MW Caterpillar Diesel

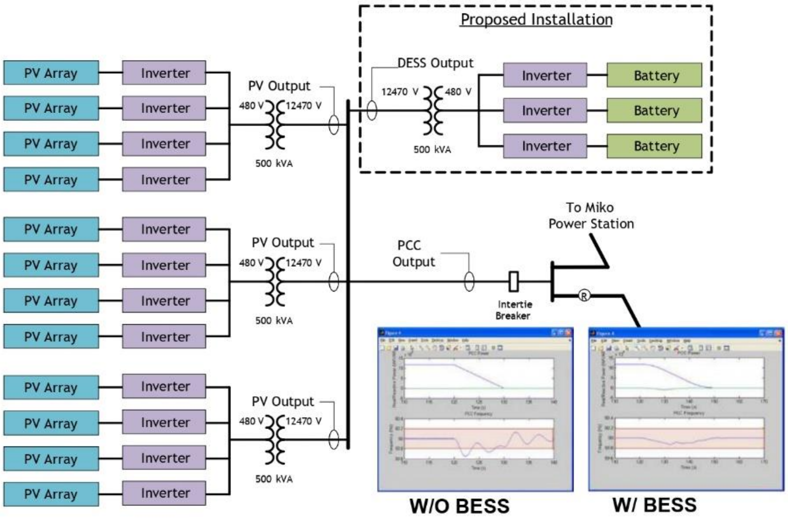
1.2 MW PV Plant

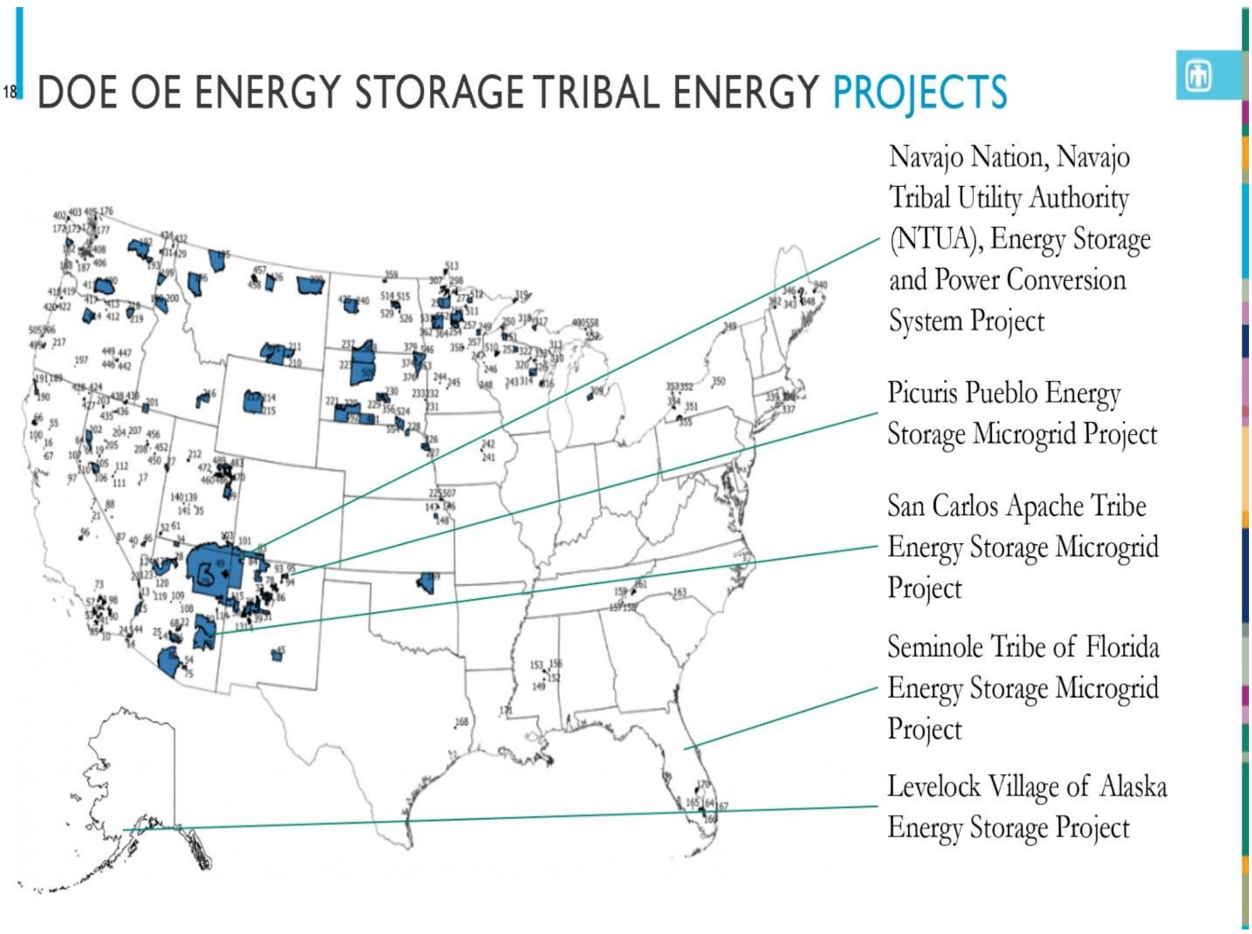





# LANAI GRID ENERGY STORAGE CONTROL PROJECT





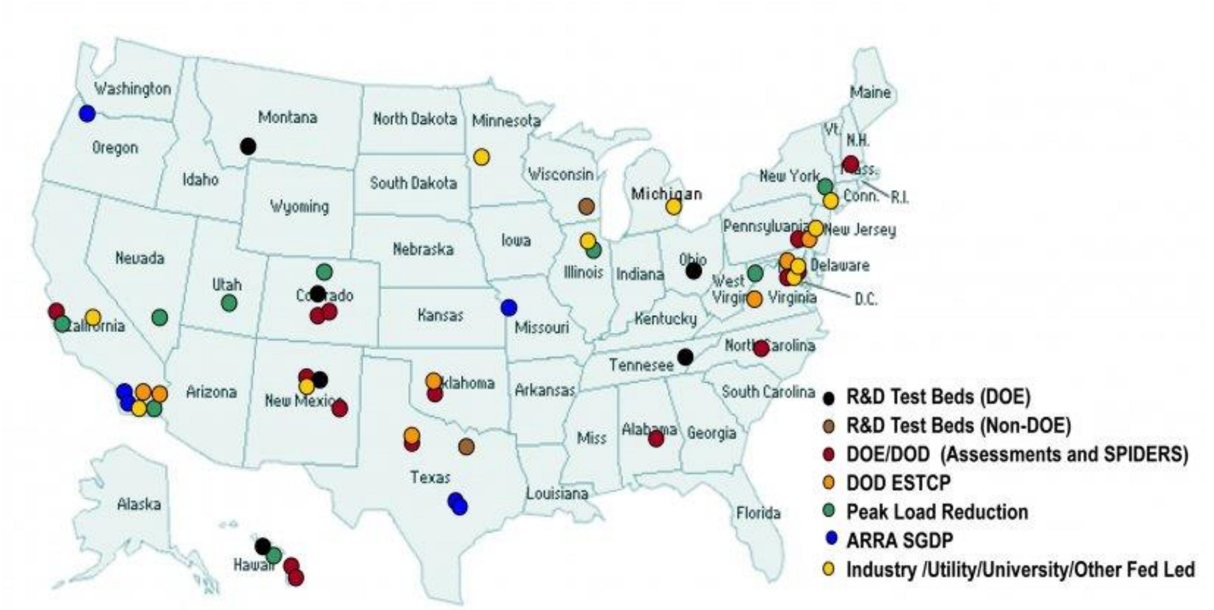




**FIGURE : Current microgrid landscape of USA**

# FUTURE SCOPE OF MICROGRID

The future for microgrids is bright - one of the biggest trends impacting how microgrids will evolve is the ability to store energy. While about one third of microgrids now include electrical energy storage, solution providers have a long way to go to make this technology universal for the widest impact.

Technology innovations will create an environment where microgrids will be able to sync with each other more effectively. Software will develop to a point where small microgrids will be able to communicate with each other and balance energy requirements when needed. When microgrids work together, they'll be able to provide more reliable energy and provide power more universally to urban, suburban, and rural areas.

The need for microgrids is apparent - what's left now is for regulators, consumers, utilities and private companies to work together to determine opportunities to build a network of reliable, efficient and clean energy. Continued investment and adoption of microgrid technologies - from storage to solar and controls - will lead to new ways of thinking about how we consume and produce power, and will create more reliable energy supplies for generations to come.

## Trends for microgrid

Understanding microgrid trends is critical to both end-users interested in transformative technologies and developers expanding into growing markets.

Microgrids are playing a growing role in the evolution of the traditional electricity system toward a more distributed and modern grid. While microgrids are usually deployed in remote communities and military bases to provide energy independence and resilience, they now provide these benefits to local communities, college campuses, and even manufacturing centers.

Understanding the following microgrid trends is critical to both end-users interested in transformative technologies and developers expanding into growing markets.



## Trend 1: Utilities see profits in mixed ownership

More utilities have emerged in microgrid ownership by partnering with third parties in a mixed model. In Woodbridge, CT, United Illuminating partnered with the town to own distributed energy resources (DERs) used to power critical infrastructure assets within the town. UI owns and maintains the fuel cell that powers the microgrid, while the town owns and controls the microgrid itself.

During normal operation, the fuel cell provides grid electricity; but during an outage, it will operate as an island, providing power to the Woodbridge Town Hall, library, firehouse, police station, public works, high school, and senior center.

Community microgrid models are also on the rise as cities seek distributed generation to provide more resilient and clean power. Policy initiatives and programs promoting resilient and distributed grid strategies, such as NY Prize, are the key to unlocking future growth in the community microgrid space.

The current microgrid ownership models still favor end users, while utility ownership is more prevalent in remote and island communities – however, we may see more towns like Woodbridge develop as utilities become attracted to the mixed model.

## Trend 2: Solar leads the way

To date, the majority of installed microgrids are anchored by efficient CHP systems, which often include other technologies such as solar PV and energy storage. Despite a significant amount of planned deployments for CHP-based microgrids, solar currently leads the way for planned capacity.

Many planned solar-based microgrids are scheduled to be included in community or military microgrids across the U.S. There are also significant opportunities to deploy solar and storage alongside existing CHP installations.

## Trend 3: The map determines the microgrid

The majority of operational and planned microgrids are located in the Northeast, with a large portion also positioned in California, Hawaii, and Alaska.

Extreme weather in Northeastern states like New York and Massachusetts demands the improved resistance to power outages that microgrids provide. On the west coast, renewable energy policy has driven California microgrids. California expects more installations as the PUC responds to the new microgrid bill. Microgrids in Hawaii and Alaska are traditionally required for islands and off-grid or remote communities.

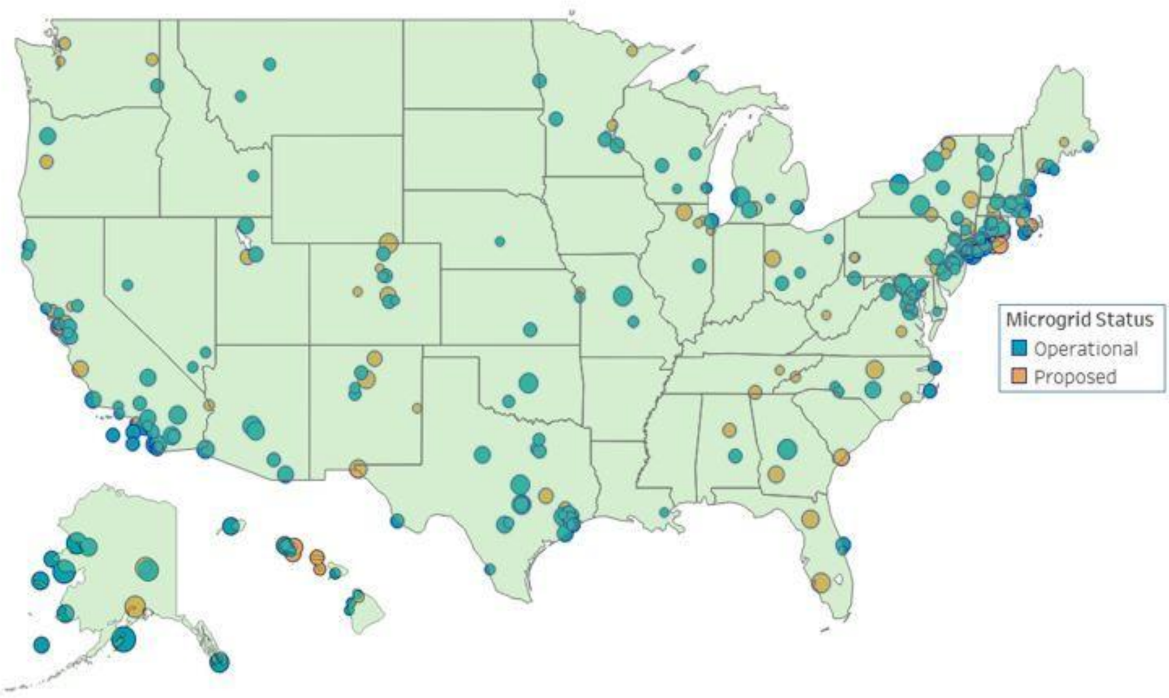
Looking to the future, there is still planned investment in traditional remote location, military, or campus-style microgrids – but a large portion of planned microgrid capacity will likely be deployed in cities and local communities to improve resiliency and meet renewable goals.

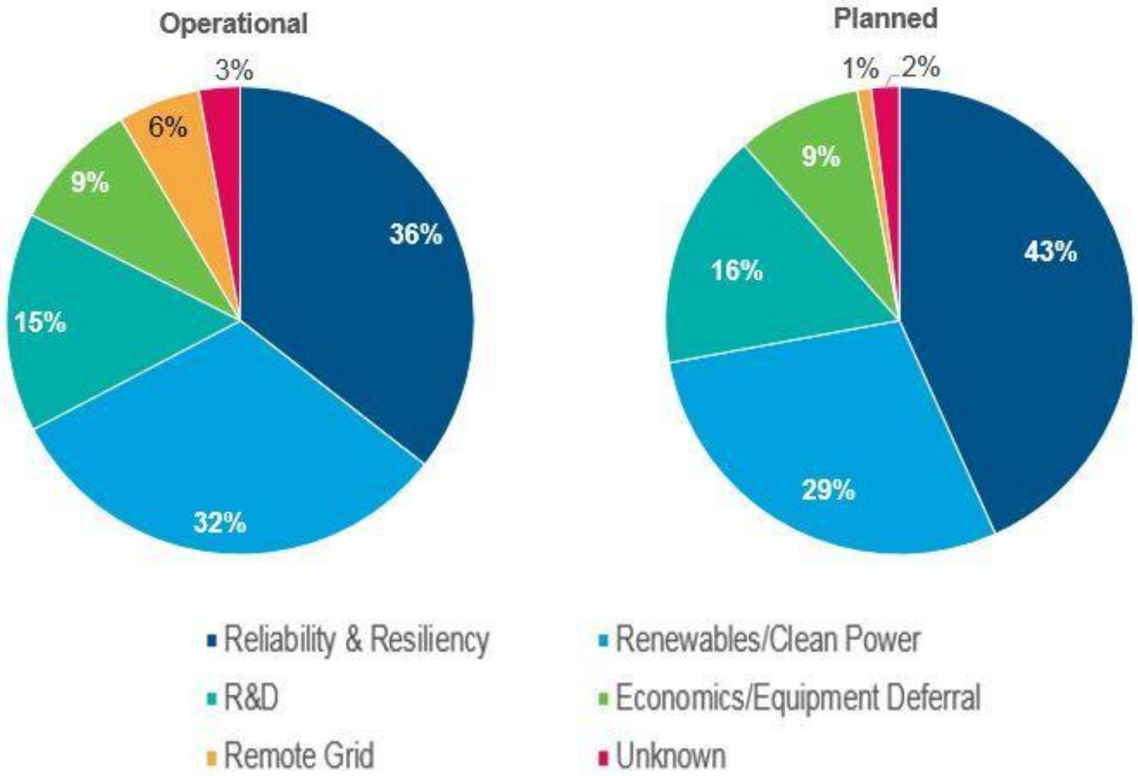
## Trend 4: Microgrid implementation drivers

End-users are still pursuing microgrids for the same reasons: reliability and resiliency, incorporating renewable energy, and research and development.

However, in recent years, microgrids have become known as a reliable and resilient power source that can maintain operation during storm events and grid outages.

Utilities interested in getting ahead in the microgrid space, including San Diego Gas & Electric, are partnering with technology developers and customers to deploy pilot microgrid projects that can improve reliability and provide distribution-level benefits.


Microgrid Status
Operational
Proposed


Operational
3%
6%
9%
36%
15%
32%
Planned
1%
2%
9%
16%
43%
29%
Reliability & Resiliency
Renewables/Clean Power
R&D
Economics/Equipment Deferral
Remote Grid
Unknown

# CONCLUSION

This paper proposed a microgrid design framework based on power system analysis and techno-economic analysis, which targets practical microgrid designs. Techno-economic analysis simulates the power balance of a microgrid considering economic prices and operating constraints of DER units, and the simulation is typically performed with annual operation data on a 1 h time-step resolution. Techno-economic analysis cannot evaluate the power system performance criteria, such as voltage and frequency regulations, which are essential for system operation when the micro grid design is implemented in practice. Accordingly, power system analysis is vital for a complete microgrid design. The optimal microgrid configuration obtained by the proposed method satisfies the de-sign objective in terms of economic efficiency and the power system performance regulations, thereby enhancing the realistic feasibility of the microgrid design solution. The effectiveness of this approach was validated by applying it to a real stand-alone micro grid design for Deokjeok Island in South Korea. The case study results justify the importance of considering power system specifications in the microgrid design process. The power system conditions affect not only the technical performance but also the optimal microgrid design. Considering the power system improvements, the selected optimal design for Deokjeok Island microgrid maximizes the system economic efficiency and provides high power system performance. This result indicates an advantageous application of the proposed microgrid design framework that is to evaluate the impacts of different power system design options on the optimal microgrid configuration. In practice, the planning and design of microgrids must consider local conditions of the site to obtain the most technically and economically feasible solution. This study can be a reference for microgrid designers seeking a complete microgrid design process that can be adopted in practical design problems and provides a means to evaluate technical and economic variants in the design solution. The presented work in this paper has some limitations. The techno-economic analysis considered in the proposed microgrid design framework is based on deterministic calculation methods. We did not consider uncertainty in the required time-series data such as power demand and weather resources data. This is currently the most common approach in the micro grid planning and design process. However, this method cannot capture the intermittency in RES generation, which is a technical challenge in real-time micro grid operation for high renewable energy penetration. By incorporating power balance uncertainty in the performance model of the techno-economic analysis, the simulated operation of a microgrid can be more accurate for actual systems.

# Reference


- electricenergyonline.com/energy/magazine/884/article/Microgrids-Changing-the-Face-of-Energy-Output-and-Consumption.htm
- https://www.osti.gov/servlets/purl/1132769
- https://ieeexplore.ieee.org/document/5944702
- https://www.researchgate.net/figure/Reliability-results-of-microgrid-system_tbl2_322731383
- https://www.frontiersin.org/articles/10.3389/fenrg.2021.591537/full