Powering 10G: The Role Of Microgrids

A Technical Paper prepared for SCTE•ISBE by

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1. Introduction

This paper is a joint effort by members of the SCTE Alternative Energy / Microgrid Working Group. The SCTE Alternative Energy / Microgrid Standards Working Group's (AE/MGWG) charter is to "educate and inform the SCTE community on the applicability and use of alternative energy & microgrid technology in cable operator facilities." This includes: defining operational practices and standards; demonstrating the technology is deployable and manageable for service providers; facilitate communication between service providers, industry partners and other standards organizations; and creating a library of microgrid use cases showing how resiliency can be improved, operational costs reduced, and deployment times decreased through the appropriate application of these technologies.

A microgrid is an electrical system that connects multiple sources and loads that is controllable by the user to allow independent operational choices. Currently, some basic alternative energy and microgrid technology have been deployed throughout the cable industry. However, the industry has not yet taken full advantage of existing, available, and relevant advanced powering technologies. Most existing power systems are not ready to work like advanced microgrids. That said, cable operators can, and should, continue to leverage already deployed technologies and test the new approaches to powering. This paper will attempt to address how microgrid technology has continued to evolve, along with the issues facing the application of future microgrid technologies, to illustrate the benefits of adopting a proactive rather than reactive microgrid implementation strategy.

Today, traditional deployments of energy infrastructure in the cable industry includes Direct Current (DC) power plants and Alternating Current (AC) uninterruptable power systems, long term battery storage, transfer switches and switch gear. It also includes generator sets, renewables and other power sources that have been combined in a traditional manner to provide resiliency and sustainability when grid power is lost. While these are many of the basic elements of a microgrid, they often lack the topology and controls required for full microgrid implementation and performance. However, existing deployments are capable of providing a foundation for transition into a more resilient and functional microgrid architecture.

The fundamental premise behind the deployment of a true microgrid architecture by a cable operator is the increasing opportunity to diversify sources of power and therefore enable a more resilient service offering to customers. This would also allow new capital models and power system topology designs to reduce cost of ownership.

2. 10G and the Aging Power Grid

2.1. 10G Defined

The cable industry is quickly moving the needle of network service offerings. The collective initiative was announced as 10G at the 2019 CES show in Las Vegas. This collective push to offer a symmetrical 10 gigabit network to subscribers will enable new ideas, businesses, and things not yet imagined coming to life. "The 10G platform is a combination of technologies that will deliver internet speeds 10 times faster than today's networks and 100 times faster than what most consumers currently experience. Not only does 10G provide faster symmetrical speeds, but also lowers latencies, enhanced reliability and better security in a scalable manner." [1] Powering will continue to be an important component to this developing program, and just like the network will evolve, power strategies should evolve as well.

2.2. Aging Infrastructure and the Grid

The U.S. electric grid ("the grid") constitutes a vital component of the nation's critical infrastructure and serves as an essential foundation for the American way of life.

America's economy, national security and even the health and safety of our citizens depend on the reliable delivery of electricity. The U.S. electric grid is an engineering marvel, with more than 9,200 electric generating units having more than 1 million megawatts of generating capacity connected to more than 600,000 miles of transmission lines, according to the U.S. Department of Energy, Office of Electricity.

This "grid" feeds consumers through an intricate network of transmission lines, substations, distribution lines, and transformers, as shown in Figure 1.

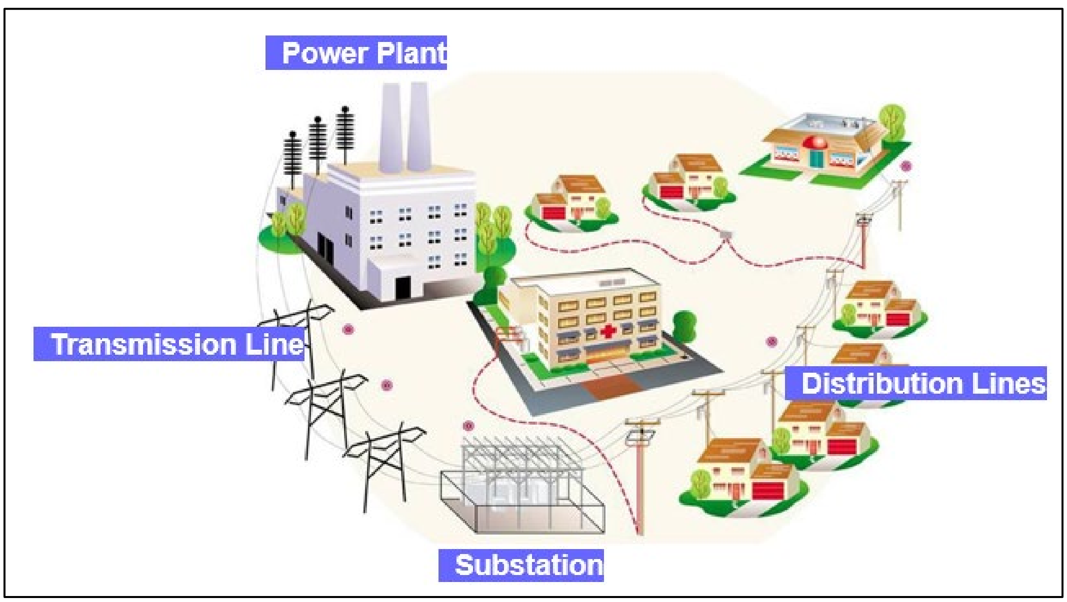


Figure 1 – Simplified Electrical Grid

It is generally understood in the industry that the electrical grid is aging. A good assessment is provided by the American Society of Civil Engineer's (ASCE) 2017 Infrastructure Report Card, which described most of the U.S.

energy system as predating the turn of the 20th century, with most transmission and distribution lines at full capacity. These systems were constructed in the 1950s and 1960s with a 50-year life expectancy. The annual number of power outages continue to increase, and the ASCE gave the system a D+, the same rating given to it in the previous three 4-year report card cycles, indicating no changes other than the system continues to age.

As a significant portion of the grid was developed and built half a century ago, it did not include the present-day demand for:

- Higher quality power
- Integration of clean, variable renewable, electric vehicles, and distributed energy technologies
- Remote control and data gathering
- Enabling consumer participation
- Higher security and protection from vandalism, terrorism, and weather

The grid was built to simply deliver power with ease of operation, economically, efficiently, and reliable for the age.

This grid connects numerous utilities which are individually focusing on replacement and upgrade as priority over other issues such as aging workforce, regulatory models, and stagnant growth. Meanwhile, they are developing and improving processes and models to manage their assets more efficiently such as:

- New and innovative testing methods, which help to identify and prioritize old equipment that is most in need of repair and/or replacement
- Cable injection and treatment programs
- Breaker refurbishment and upgrade programs
- Wood pole and tower structure testing, treatment, and replacement

Unfortunately, these programs allow the basic infrastructure to continue to age.

2.3. Reliability & Resiliency (eg: Ca. Public Service Power Shutoff (PSPS Program!)

Cable operators are observing compound annual growth rates (CAGR) of 40 – 50% downstream and 20 – 30% upstream driven by streaming video (including 4K content); newer, delay-sensitive gaming applications; and a general increase in consumption. Over the next few years, cable operators will be faced with numerous decisions in order to meet the exponentially growing needs of their customers.

The upcoming implementations of 10G networks, which promise 10X the bandwidth, assure that there will be an increased need for reliable energy to drive these more powerful devices as they are deployed across the network. This increased demand for powering cable plants and networks comes at a time when traditional utilities are grappling with a myriad of issues, including the fact that they have failed to keep up with the increasing need for truly resilient energy across their mostly centralized networks. This can pose another serious challenge that cable operators will need to contend with.

What's more, to contend with existing and up-and-coming competitors, cable operators are also increasing their dependence on reliable and consistent power to service newer offerings that are being driven by the proliferation of Internet of things (IoT) applications, including in-home security systems and other "smart devices." This all increases backhaul requirements and intensifies the demand for resilient and reliable power.

These dynamics are forcing operators to reconsider their investment strategies and the soundness of making longer term capital expenditures to reduce risk, reduce costs and remain competitive. Microgrids may provide a viable strategy, by reducing the dependency on traditional power providers with the possible concurrent benefit of reducing energy-related operating expenses over time. Fortunately, many cable operators have been quietly engaged in building out what could be considered microgrids of sorts. By installing renewables and energy storage systems, operators are adding resiliency and maintaining operations in the event of power failures resulting from disruptions in the power grid. An additional benefit of these hybrid microgrids can also be realized by reducing demand charges and possibly reselling power to utilities under power purchase agreements. Other drivers of the trend to increase independence from traditional providers are the increased intensity, regularity, and length of weather disruptions, and the inability of utilities to easily make enhancements to their generation and distribution capabilities. Issues related to localities objecting to pipeline placement, new power line installations and other regulatory challenges are adding to risks associated with dependency on traditional utility operators. Operators in California have recognized the potential for such grid disruptions and have begun to respond by promoting centers in areas less likely to be impacted. Figure 2 provides a list of electrical infrastructure hazards and associated risks.

Natural Hazards	Human Hazards	Operational Hazards
Ice, snow and extreme cold weather	Physical attacks	Geomagnetic and electromagnetic pulses
Thunderstorms, tornados and hurricane-force winds	Cyber attacks	Aging infrastructure
Storm surge, flooding and increased precipitation	Workforce turnover and loss of institutional knowledge	Capacity Constraints
Increasing temperature and extreme hot weather	Human Error	Dependencies and supply chain interruptions
Earthquakes		Inherent instability from renewable resources
Wildfires		

Adapted from Argonne National Laboratory, 2016

Figure 2 – Growing Risks to the Electrical Infrastucture

Growing energy demand is also impacting the existing industry growing risk situation. Despite increased efficiency, the US Energy Administration projects that world energy demand will increase by 28% by 2040. Much of this demand is driven by the increasing digitization of society, data centers, telecommunications systems, and our households, that continue to require more energy to operate the devices we have become so dependent upon.

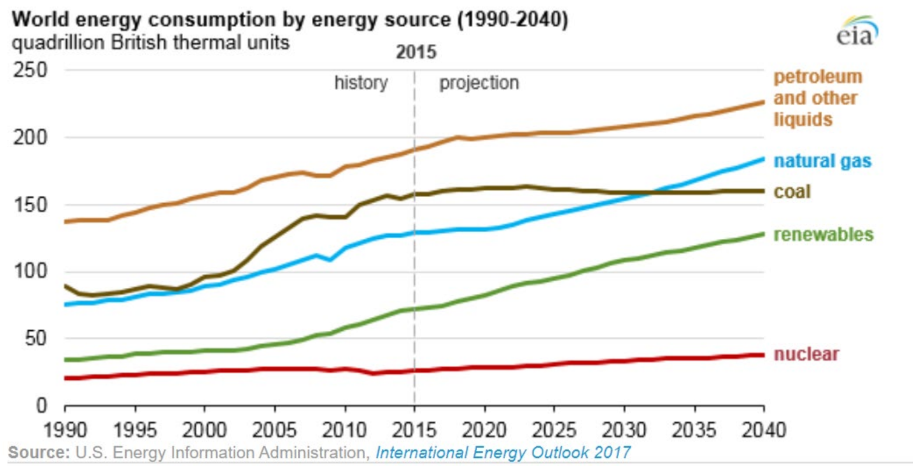


Figure 3 – World Energy Consumption

Also compounding the problem is the increased intesnity and frequency of major storms, fires and other natural disasters. Outages of more than 24 hours impact every citizen. Food supply, manufacturers, communications networks, and simple changes to every day routine have consequences beyond financial. Also to be considered are the financial and manpower resources required to respond to such events, the pressure on traditional utilities to modernize generation and distribution networks, and the impact on our communities.

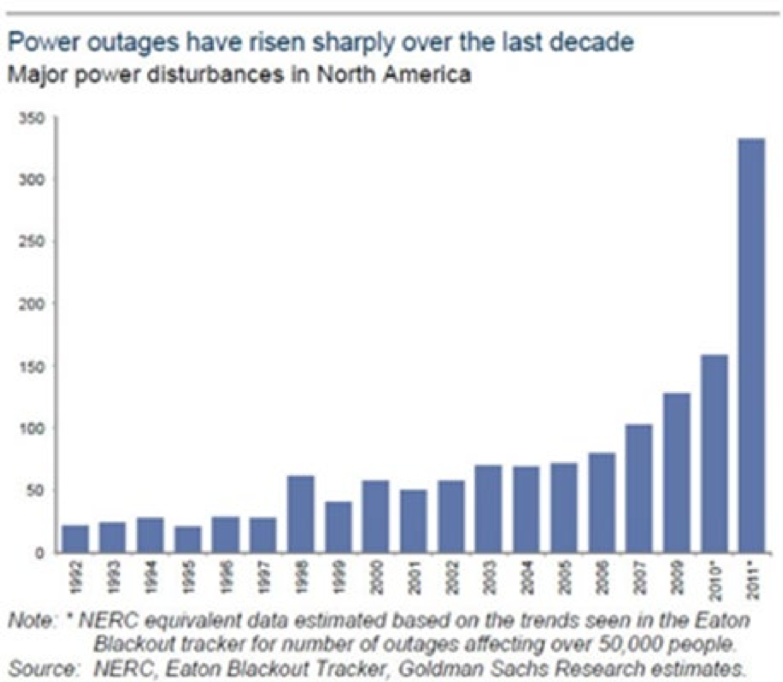


Figure 4 – North American Power Outages

The demand for quality, dependable power is also extending beyond primary cable plant and includes the growing demands of peripheral (edge) requirements for power as the technology evolves. Utility costs for these edge sites is also increasing along with the risks of losing utility power. Power fundamentals such as native DC vs. AC supply of energy also adds to the cost and complexity of supporting cable operations. With recent advances in direct current technologies and deployment capabilities DC powered networks can increase system efficiency, particularly as the industry integrates native dc powered renewables and energy storage devices into their power networks.

3. Microgrid Defined and the role of alternative energy resources

3.1. What is a microgrid?

The SCTE Alternative Energy/Microgrid Standards Working Group (AE/MGWG) developed a definition for microgrids as: "Microgrids may be defined as a localized group of interconnected and managed electricity sources, storage and loads that can be connected with other local microgrids and/or the traditional electrical utility grid (macro grid) but can seamlessly and selectively disconnect from them and function independently as conditions, policies or economics dictate."

3.2. Simplified Definition

A more simplified definition of a microgrid can be stated as: A microgrid is an electrical system that connects multiple sources and loads that is controllable by the user to allow independent operational choices.

3.3. Distributed Energy Resources (DER)

The United States electric grid is comprised of bulk power generation, distribution, transmission, and consuming entities. The infrastructure enabling just about everything in our modern daily lives has remained largely consistent for close to one hundred years. AC power is generated, moved in higher voltage from generation to substations, and voltage is reduced to feed transmission and then ultimately converted into the low voltage AC power typically used at commercial and residential facilities.

With the advent of solar and what we refer to as "alternate energy" sources, the model of bulk power sources begins to be challenged. The traditional grid model is one of stability, predictability, and regulation to uphold high expectations of availability. To satisfy these expectations of high availability the current system is made up of large central base-load fossil fueled power generation plants and supplemented by addition fossil fueled based peaker plants when demand increases beyond base load capabilities or are needed to supplement when base load system is unavailable. When we plug something into an electrical outlet here in north America, there is no second-guessing power availability. Distributed energy resources can become a viable model to anyone wishing to pursue alternatives to the traditional power grid.

The new challenge of incorporating solar photovoltaic (PV) systems, wind resources, storage (like batteries) raises electrical engineering questions as well as financial market questions. DERs can be defined as: "Distributed energy resources are small, modular, energy generation and storage technologies that provide electric capacity or energy where you need it. DER systems may be either connected to the local electric power grid or isolated from the grid in stand-alone applications. DER technologies include wind turbines, solar/photovoltaics (PV), fuel cells, microturbines, reciprocating engines, combustion turbines, cogeneration, and energy storage systems."[2] Cable operators are in a very good position to evaluate and deploy DERs due to hybrid fiber coax (HFC) communication network architectures. Critical facilities, people space and even outside plant can be considered for distributed energy adaptation.

There are several use cases that can promote the deployment of a DER for cable operators. These primary cases include lowering grid dependency, becoming less utility grid dependent, and enhancing availability of power. In locations where peak demand charges become very high during seasonal changes (high air-conditioning or heating needs), a local DER such as a grid-tied PV plant can help reduce excess charges. The PV plant can be engineered to match the forecasted spikes in utility grid demands that associate with a higher billing to the cable operator. In 2019, California power providers began to institute public safety power shutdown (PSPS) events. Weather conditions supporting high fire risks have required grid providers to turn off supply in order to lower risks of fire. Communication providers need to become less dependent on the grid to ensure service availability. DERs can help address that need. This approach is naturally related to the third use case of enhancing power availability. NREL conducted a backup power study for cable operators and that report can be found in Reference [3].

Distributed energy resources can play an important role in cable's infrastructure. Determining the strategic adoption can be done following a few steps. First, identify the electrical requirement and/or problem. Are the bills too high? Is power availability becoming unacceptable? Are there renewable energy requirements needed for positive marketing? Does run-time in the absence of grid or traditional generator backup need to be extended? After the applicable question/s is/are identified and answered, the technology can be identified to address the problem. PV has been a reliable go-to; however, each situation will dictate what power generation source would fit best. Second, approach the local utility provider to discuss incentives. If the local power provider has a mandate to lower loads or incorporate renewable power sources, there may be financial awards to help offset DER deployment costs. Third, build out the project plan to commissioning. As with any change to day-to-day operations, a DER implementation requires a solid project plan to ensure successful incorporation into existing network topologies. Finally, document post commission needs, such as maintenance, system milestones and support providers. Cable operator infrastructure requires working with a multi-vendor ecosystem and the DER turn-up can introduce new providers of power service if the existing pool of resources do not specialize in essential power source management. This relationship will be especially important as a DER investment can extend beyond 20 years.

3.4. Alternative verses Renewable Energy Resources.

The differences between "alternative energy," "renewable energy," and "clean energy," might not be obvious. Each term is unique and has its own individual definition.

3.4.1. Alternative Energy

Alternative energy refers to sources of usable energy that can replace conventional energy sources (usually, without undesirable side effects). The term "alternative energy" is typically used to refer to sources of energy other than nuclear energy or fossil fuels.

Throughout the course of history, "alternative energy" has referred to different things. There was a time when nuclear energy was considered an alternative to conventional energy and was thus called "alternative energy." The term is ever evolving.

Today, a form of "alternative energy" might also be renewable energy, or clean energy, or both. The terms are often interchangeable, but not the same.

3.4.2. Renewable Energy

Renewable energy is any type of energy which comes from renewable natural resources, such as wind, rain, sunlight, geothermal heat, and tides. It is referred to as "renewable" because it does not run out.

People have begun to turn to this type of energy due to the rising oil prices, and the prospect that one day sources of fossil fuels may be depleted. Also, concerns about the adverse effects that our conventional energy sources have on the environment have played a big role in the advancement and adoption of renewable energy sources.

Among the different types of renewable energy, wind power is one which is growing in its use. The number of users who have some form of wind power installed has increased, with the current worldwide capacity being about 100 GW. In addition, the traditional power grid has leveraged commercial wind farms to diversify power sources in environmental correct locations such as the mid-west and parts of Texas.

3.4.3. Clean Energy

"Clean energy" is simply any form of energy which is created with clean, harmless, and non-polluting methods. Most renewable energy sources are also clean energy sources, but not all.

One such example is geothermal power. It may be a renewable energy source, but some geothermal energy processes can be harmful to the environment. Therefore, this is not always a clean energy. However, there are also other forms of geothermal energy which are harmless and clean.

Clean energy makes less impact on the environment than our current conventional energy sources do. It creates an insignificant amount of carbon dioxide, and its use can reduce the speed of global warming – or global pollution.[4]

3.5. Bringing Alternative Energy Resources Together = Microgrid.

Typical cable industry critical infrastructures (CIs) are constructed with power systems that contain emergency back-up systems, such as fossil fueled generators and lead acid battery-based DC power plants, to ensure system reliability during utility power outage events. A typical system configuration example is shown below in Figure 5.

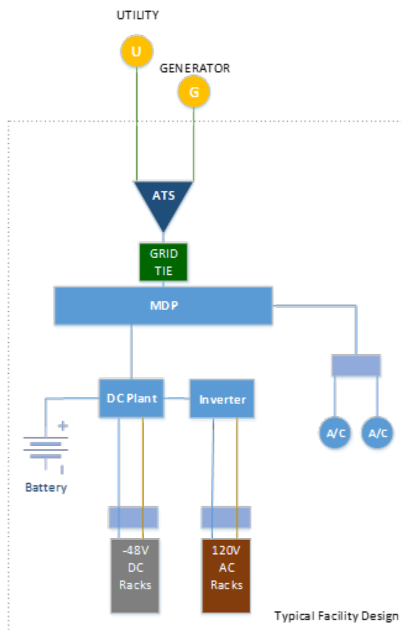


Figure 5 – Typical System Configuration

The current state of this infrastructure is characterized with specific technologies characterized by the functions and related adjacent operational functions as described in Table 1.

Table 1 – Infrastructure Operational Functions

Business Function	Technology	Technology Function	Operational Considerations
Primary/Secondary Power Source	Utility Service and Generator	To power the critical load	• Site is dependent upon reliable utility service • Site operates on either utility OR generator • A brief outage is required for generator start-up • Most generators are fossil fuel based • Many sites with dual generators
Source Transfer	Automatic Transfer Switch (ATS)	Monitor utility power and controls	• No parallel operation • No closed transition transfers

		transfer of power source	
Power Distribution	• -48v DC/battery plant • Dual bulk feeds to critical loads	Service continuity during transition from utility to generator	• High initial investment with stranded capacity costs • Assorted power distribution configurations • System changes and adds are costly with specialized labor and material which can influence time • Power density varies widely but initial build investment needs to anticipate worse case loads • Inverters can allow for elimination of UPS
	Inverter	Critical AC loads through inverter (eliminating UPSs in process)	
Stable Operating Environment	HVAC		• Backed up by generator for power during commercial power outages

Bringing a variety of power sources together to feed and support a load or multiple loads is a microgrid. The cable industry, to some extent, has a head start in the progression path to microgrids that should be evident from the above. Some examples of microgrid topologies are shown on the following page.

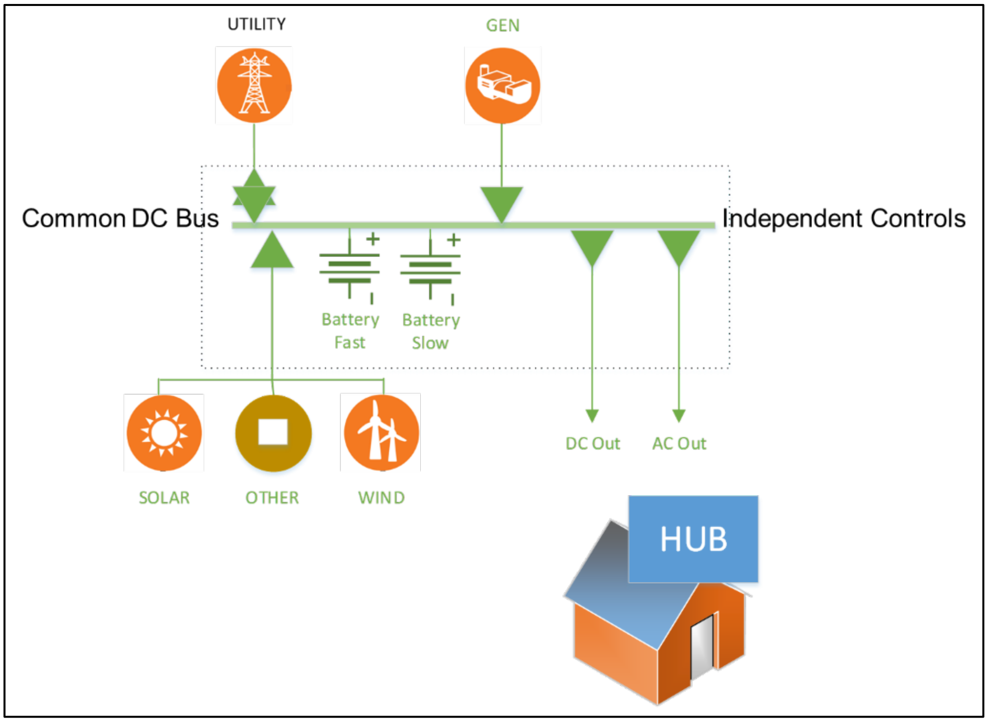
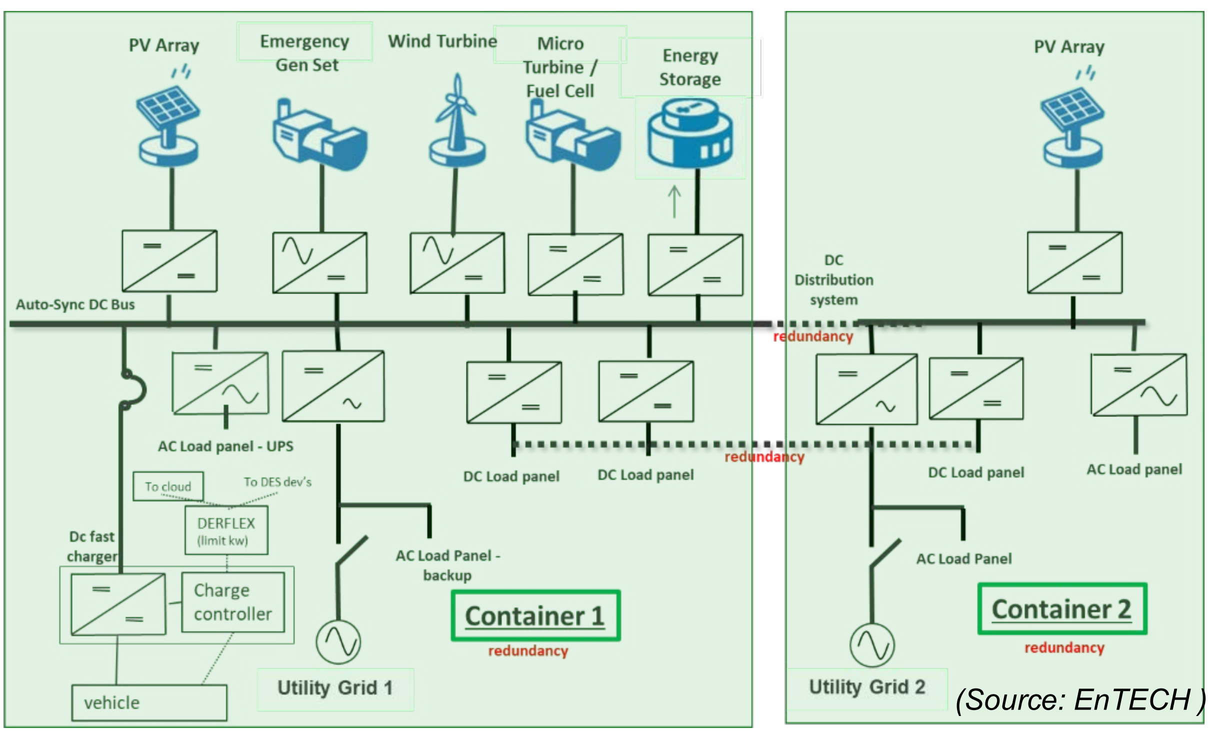


Figure 6 – Microgrid Topology (1)



(Source: EnTECH)

Figure 7 – Microgrid Topology (2)

The preceding configurations use a DC power collector bus topology. An example of an AC power configured microgrid is shown in Figure 8 (Source: Schneider Electric).

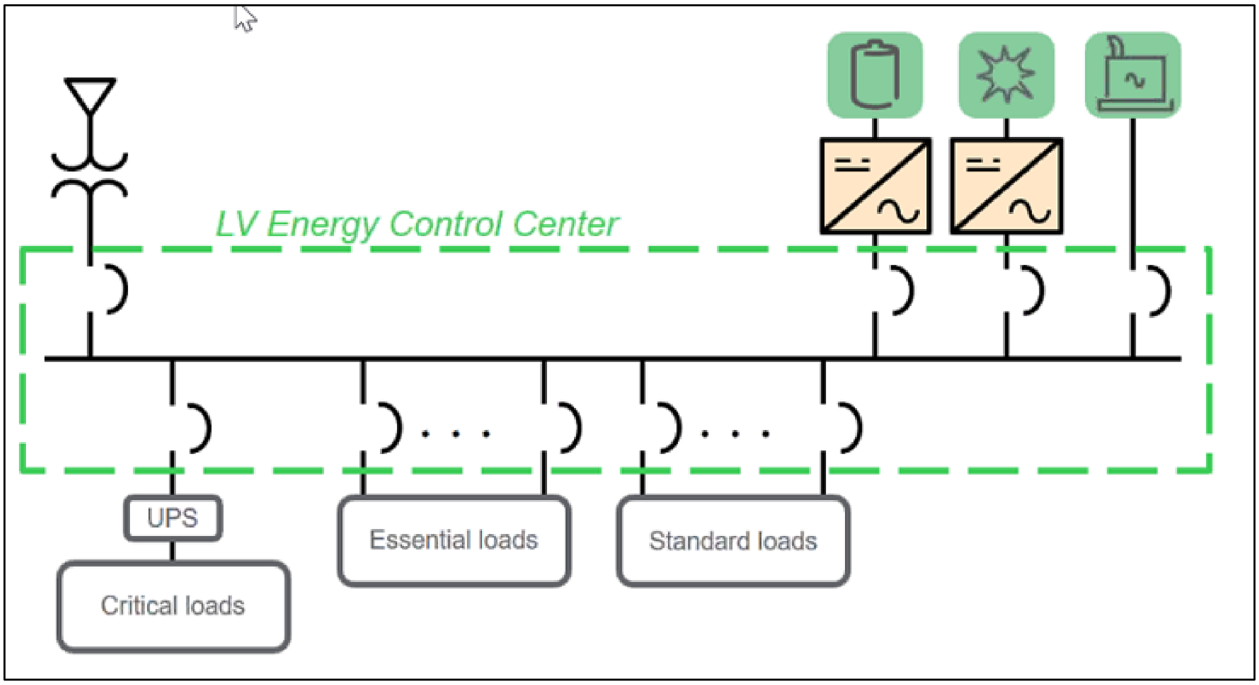


Figure 8 – Microgrid Topology (3)

3.6. What's In It for the Cable Industry/Cable Operators?

The DOE and other government agencies have been spearheading the definition of microgrids while documenting their value. Now, with the active involvement of two predominant industry organizations - NREL (National Renewable Energy Laboratory) and CableLabs - this should send a clear message that it is time for the cable industry to grab the lead, creating microgrid standards specifically designed for cable operators.

As introduced earlier in the paper, microgrids are very important to the cable industry for several reasons:

1) They provide additional resiliency and reliability in times of unplanned power outages. During severe weather, microgrids can provide the ability to continue providing power to critical facilities.
2) With competitively priced self-generation from renewable and other energy sources, microgrids can provide a hedge to increasing costs of energy for cable operations.
3) Coincident with time-of-use electricity pricing, microgrids can allow cable operators to buy low and sell high for their operational energy needs, as well as the energy needs of their customers.
4) Microgrids provide operational independence from local utilities allowing control and usage of dispatchable power sources independent of local utility performance.

Operational cost containment is an important practice for cable operators, and power is no exception. The idea of purchasing energy at low rates and selling high over a 24-hour period will become increasingly important. Time-of-use rates become pervasive to effectively manage the supply and demand balance of the grid in the presence of increasing renewable energy resources. This is evidenced by the increasing number of cities, states and countries that have made 100% renewable generation commitments, most notably, the states of California, Hawaii and several others by 2045.

While these economic drivers are valid, other areas of the country with lower electrical costs are justifying microgrids by combining other value propositions with Time-of-use gains. Such benefits include added resiliency, demand shaving, and the utilization and control benefits of higher voltage direct current in a DC-Coupled microgrid.

Basic microgrid technologies are currently deployed within the cable industry, but they are not positioned to best leverage traditional microgrid techniques. The opportunity exists for the industry to take stock of what is changing in their networks, followed by an exploration of how the industry should or can leverage new technologies (including power). As the industry strives to enhance the customer experience, there needs to be a conscious review of how energy use has evolved. As new cable technologies are deployed in the access networks, infrastructure costs to accommodate these changes could end up being fiscally prohibitive in meeting business goals without proper consideration of modular microgrid technology deployments.

The regionalized nature of the cable industry is conducive to microgrid developments. The cable industry could develop microgrids and sell power to/within itself as well as sell power to outside partners. The steadily improving return on investment (ROI) related to microgrid and alternative energy technologies, coupled with regionalized opportunities that exist for the cable industry/cable operators, make a valid argument that there are tangible benefits for microgrid development.

4. MicroGrid use cases and drivers for the Cable Industry

4.1. Edge Facilities and Outside Plant

It is well documented by SCTE, and as depicted in Figure 9, that the majority of the cable industry's critical infrastructure power footprint is housed within edge facilities and outside plant.

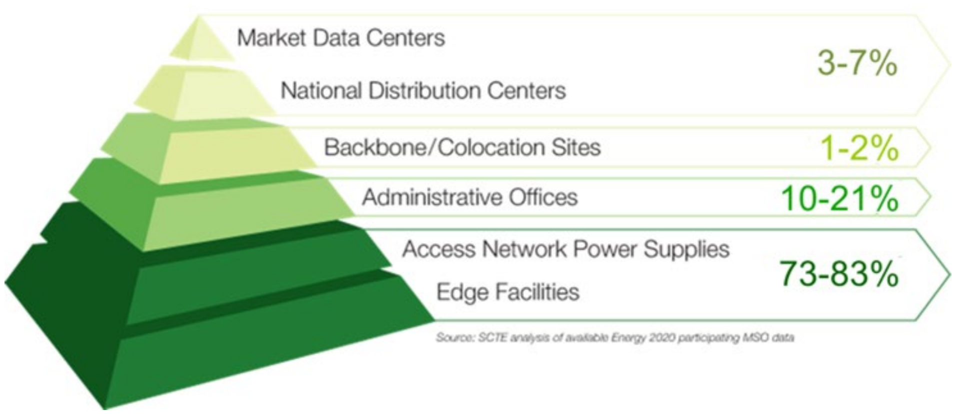


Figure 9 – Critical Infrastructure Facilities

Outside Plant Infrastructure: Unique to cable and telecom providers is the outside plant and especially the hundreds of thousands of power supplies enabling the hybrid fiber coax network (HFC). Typically, power is provided to the center conductor of the HFC plant via a local power supply. The power supply receives power from the utility provider typically on the very same pole the cable infrastructure resides. What kind of creative approach could be taken to address the diverse nature of outside plant powering? Self-generation of power in strategic places could be an opportunity for investigation. New innovative power supplies and infrastructure are being investigated and new standards are in process to allow this innovation. New energy storage technologies will also play an important role.

Edge Facility Infrastructure: According to ANSI SCTE 226 2015, Class B-D facilities are smaller in nature, support, and design criteria than the larger Class A data center centric facilities. This does not mean that the importance of these infrastructure rich points of presence are small. Evaluation of microgrid deployment options are not easy to determine. Careful examination of each facility should be conducted, and a reusable model built to evaluate the benefit and application of microgrid options at the smaller facilities. The model needs to consider multiple data points such as downtime, cost of power, number of subscribers, and types of subscribers (commercial vs. residential). Network architecture dependencies are important factors when determining microgrid investment. All new infrastructure power solutions must be modular and scalable.

4.2. Electric Vehicles (EVs)

The cable industry maintains a fleet of nearly a quarter million vehicles worldwide. In recent years, the industry often encourages technicians to overnight company vehicles at their homes. Continuing to do so will create unique financial opportunities to leverage the industry's broadband infrastructure to manage the charging of cable's future fleet of EVs—and perhaps even private vehicles—across small and large geographic areas.[5]

EVs and hybrid EVs will play an increasingly important role in cable operations. Due to technological advances and continuing declines in battery costs, personal EVs provide fuel savings of nearly $1,000 per year and EVs overall are cheaper than equivalent combustion-engine models for many applications. Deployment of EVs are increasing every year and should be part of microgrid applications and growth. This will help fill the need for increased power reliability and resiliency.

Global decarbonization is driving the further electrification of our world and this will result in increased electricity consumption of 38% by 2050[6]. Electricity is rising in popularity as it is easier to transport, deliver, store, and use. Society's growing dependence on electric power is resulting in an exponential rise in consumption in applications such as data centers and EVs. In and of themselves, EVs are likely to create 20%-30% additional load on the electric grid[6], helping to make the case for the optimization of charging strategies. As such, Time-of-use pricing of electricity is legislated in several states and, along with variable pricing is expected to be pervasive.[7] The departure from fixed electricity rates raises crucial financial questions of 1) when to charge EVs based on varying electricity cost, and 2) how to enable the cable industry to specify methods that monetize the value stack created by managed fleet vehicle charging. As mentioned earlier, cost management of operations for cable operators is important to the business.

4.3. Monetizing Optimum Load Shaping and other EV-Based Grid Support Services

Several technologies and market trends are at play that can both negatively and positively affect the cable industry in terms of energy cost. With the increased deployment of EVs, the production, distribution, and use of electricity is rapidly evolving for the charging infrastructure that will be needed, creating critical functionality gaps in managing the grid. EV charging is already stressing grid capacity and affecting the cost of electric power. Yet, when networked and managed in a coordinated fashion, batteries and EVs are proving their ability to provide grid support services such as load shaping, peak reduction, and active power quality management via reactive power and frequency support. Together, grid support services from EVs can create a value stack consisting of reductions in operational costs, maintenance, and new construction of power plants, transmission, and distribution facilities.

If cable operators can reap the rewards of selling power via a microgrid and leverage the collective energy storage across a substantially large EV fleet, the benefits could be substantial. Communications and controls will play an important role in such a scenario.

Since 1882, the grid has operated such that supply from power generators anticipates and follows the demand for electricity. In recent years, the continuing decline in the levelized cost of energy from wind and solar power is such that, in much of the world, construction and operation of new renewable energy sources are less costly than the ongoing operation of existing fossil-fueled power plants. Yet, the demand for electricity is often not coincident in time with the supply from renewables, which themselves are variable and not dispatchable (i.e., not controllable). As such, widespread, pervasive coordination of demand will be valuable in orchestrating electric loads, such as EV charging, to follow the least costly forms of fossil-based and renewable supply.

A growing body of research from several U.S. Department of Energy National Laboratories and throughout industry indicates that load shaping will be increasingly important in reducing the cost of operations in the grid, microgrids, and nanogrids.[8] What is missing are methods to optimally shape load based on the holistic consideration of generation, distribution, and storage. Optimum Load Shaping (OLS) is a newly developed software-based proprietary technology to minimize power generation costs and carbon dioxide emissions that informs electrically powered devices of the forecast times of the lowest cost and cleanest supply. OLS uses an end-to-end generation-to-load algorithm that jointly optimizes supply (part 1) and demand (part 2). Efforts are underway in the SCTE Energy Management Subcommittee, Microgrid Working Group, to propose a standard that will specify the creation of an OLS, its transmission across different networks, and the actions taken by a receiving device, such as an EV or battery charger, that modifies its behavior to minimize differences over time from the OLS.

Forecast Optimum Load Shapes (OLSs) can help monetize the cable industry's future fleet of electric vehicles and facility batteries to provide the critically needed end-to-end, generation-to-load control of the electric power grid. An OLS provides grid control and consists of a set of numbers (e.g. target load for hours 1-24) that forecasts the most efficient electrical supply in grids, microgrids, and nanogrids, so that all stakeholders - generation entities, utilities, distributors, retailers, and consumers—can reduce their electricity costs and carbon emissions.

5. The Developing Microgrid Technologies and Industry Trends

As microgrids are developed in greater and greater numbers, microgrid interconnections will also increase. Interconnections will occur directly between adjacent microgrids, but in most cases will be interconnected through the existing electric utility infrastructure. Microgrids and the interconnection of microgrids require new ways to track energy use, power generation by distributed energy resources, and load control in a way that transactions between microgrid owners and operators are being developed. These situations and ongoing engineering developments are what make up the new "Transactive Energy" evolutions as described below.

5.1. New term: "Transactive Energy"

The increased use of renewable energy and distributed energy management technologies offers the potential for significant efficiency improvements through market-based transactive exchanges between energy producers and energy consumers.

To enable these sorts of exchanges, however, the modernized grid will require new economic tools and processes. "Transactive energy" is the broad term used to describe this new approach and can be defined as *"a system of* *economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."*

Figure 10 – Modernized Electrical Grid

5.2. Transactive Energy's Potential Benefits to Consumers

The following list outlines the benefits of moving to a more transactive-based energy model:

- Better utilization of grid assets: Everything from transformers and switches, to vehicle-charging stations and smart meters, can lower costs when optimized, especially during peak demand conditions.
- Greater resilience and reliability: During large storms, a reduced length and frequency of outages
- Greater control over personal energy use: Empowerment of choice and information provided to consumers
- Increased use of renewable energy resources: Gives individual consumers the satisfaction of contributing to larger societal environmental sustainability goals

The growth of a cable operator's business intelligence that is required for this evolution, including the development of artificial intelligence (AI), will evolve into a big data management platform. This platform could make for a new business opportunity for cable operators as well as provide market participation opportunities in various regions of the country.

5.3. The Natural Progression Towards Independent Energy Sourcing and Control

Originally driven by economics (cost savings) and social responsibility (energy management), the first step is the installation and application of renewable energy technologies and systems. The next steps are the progression paths to the future with a corporate version of self-actualization (maximizing potential) by participating in the energy market as both a supplier and consumer, with the ability to self-determine the most appropriate energy source based upon real-time availability and needs. The figure below describes the steps in the progression path to the Transactive Energy future

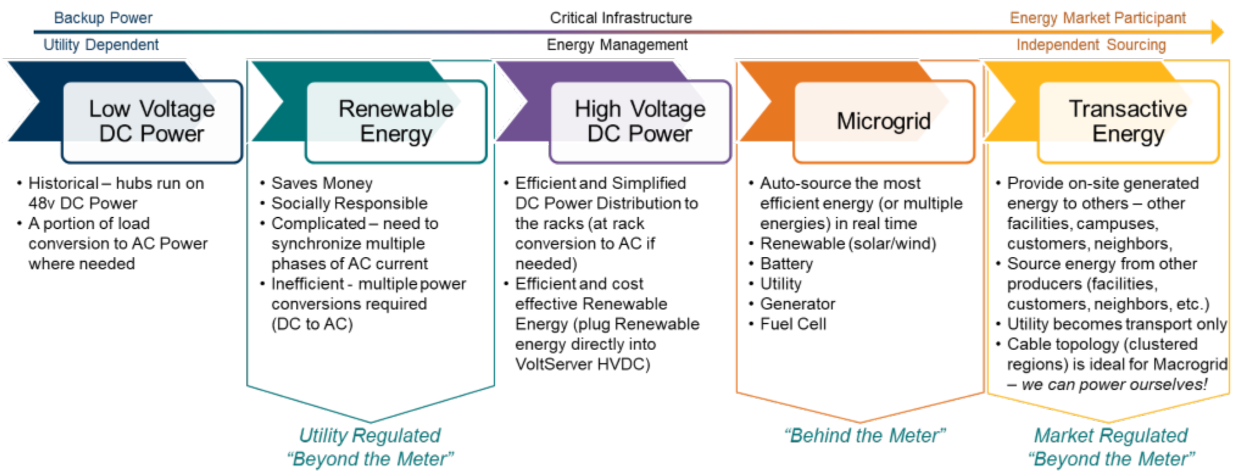


Figure 11 – Steps to Transactive Energy Market and Critical Infrastructure Resiliancy

6. Conclusion

As the cable industry looks to further standardize on strategic energy concepts like microgrids, opportunity awaits for development, trial and ultimate deployment of microgrid technologies. It has been shown that microgrids are being deployed within many industries and use cases globally. Economics, the rising cost of electricity and the focus on a more sustainable future are the drives for the widescale deployment of solar, wind and other distributed energy resources. New technology large scale energy storage is also becoming more cost effective and is playing a bigger and bigger roll in the new energy future. This paper characterized why it's a sound ideae to fully reap the benefits of multi-source smart power grid scenarios, adhering to cable specific use cases mentioned in the early sections of this paper. Finally, the consensus body represented in the active SCTE working group will pave the way to help accelerate the deployment of robust microgrid solutions. These will enable a foundation of new network ideas, as envisioned and embodied in the announcement of 10G, early in 2019. Microgrids will play a big roll in powering 10G with a summary of use cases, use scenarios and values to the industry in figure below.

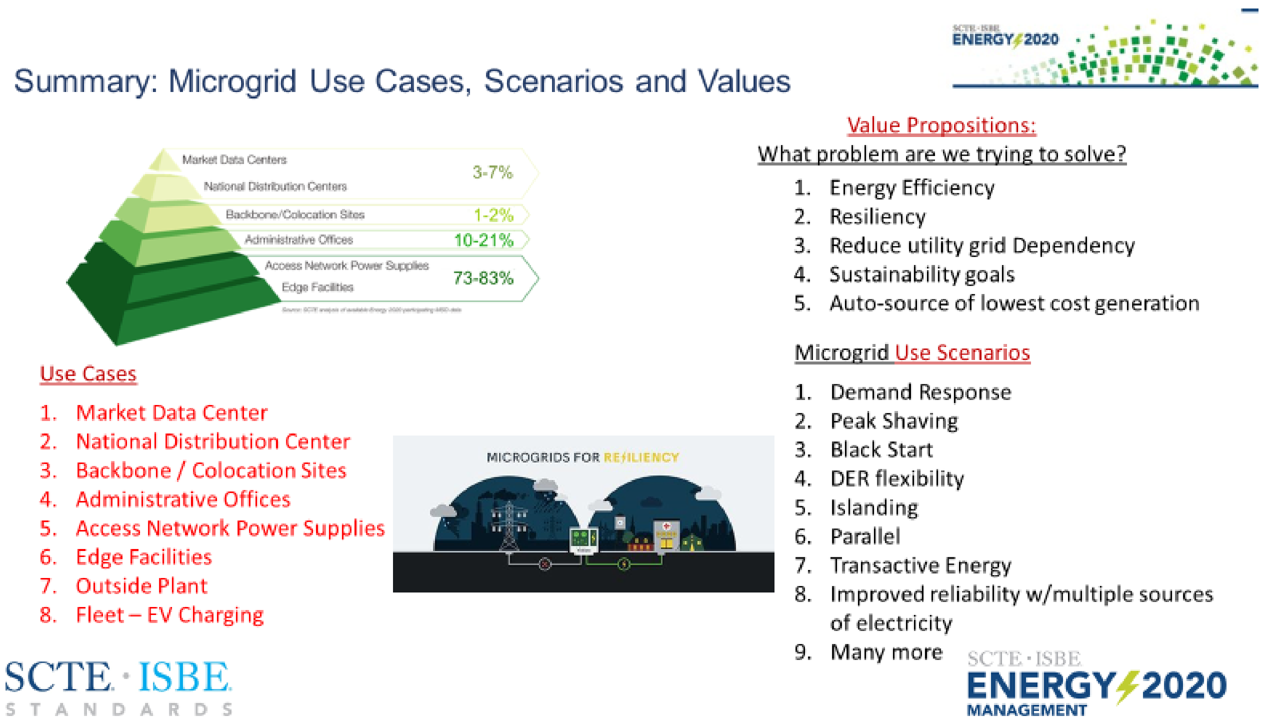


Figure 12 – Summary: Microgrid Use Cases, Scenarios & Value for the Cable Industy

Abbreviations

10G	10 gigabits per second
AC	alternating current
AE/MWG	Alternative Energy / Microgrid Working Groups
AI	artificial intelligence
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ATS	automatic transfer switch
CAGR	compound annual growth rate
CES	Consumer Electronics Show
CI	critical infrastructure
CO_2	carbon dioxide
DC	direct current
DER	Distributed Energy Resource
DOCSIS	Data Over Cable Service Interface Specification
DOE	Department of Energy
EV	electric vehicle
FEMP	Federal Energy Management Program
GMLC	Grid Modernization Laboratory Consortium
GW	gigawatt
HFC	hybrid fiber coax
HVAC	heating, ventilation and air conditioning
IoT	Internet of Things
ISBE	International Society of Broadband Experts
NREL	National Renewable Energy Laboratory
OLS	optimum load shaping
PSPS	public safety power shutdown
PV	photovoltaic
ROI	return on investment
SCTE	Society of Cable Telecommunications Engineers
UPS	uninterruptible power supply

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