



Copper Connects Microgrids with Smart Grids

Copper Usage Is Key to Modern Electric Grids

There is a new electrical infrastructure being built across America, and copper is playing a key role in its development. The general trend is the movement away from the huge, remote, utility-scale power plants of the past and toward thousands of distributed energy resources (DERs) situated ever-closer to the end-users. According to GreenTech Media Research, new electrical infrastructure in the United States has included microgrids for cities, communities, public institutions, commercial facilities, universities and remote communities such as islands [1].

A related trend in microgrids is the movement away from a one-directional passive network and toward an "intelligent network," that is, one in which data about generation and usage streams back and forth between control centers and end-users. In this manner, intelligent adjustments can be made to balance the electrical power in the grid, both locally and regionally.



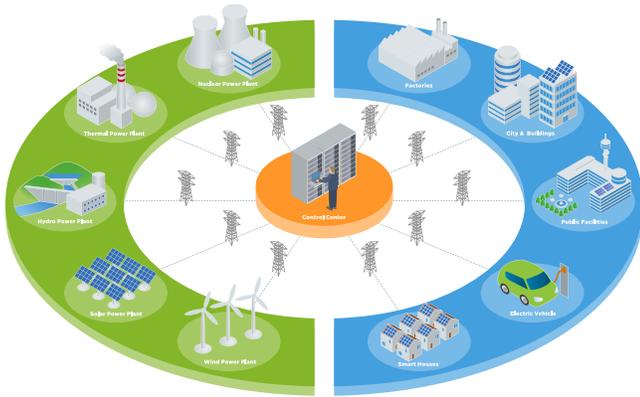
A third trend in microgrids is the movement toward alternative energy resources such as wind and solar energy, including using energy storage systems and using fossil-fuel burning plants only when alternatives are unavailable.

All of these trends will increase the use of copper. A close look at the building blocks of the new electrical grid reveals that copper usage will be dramatically increased at every level. Fortunately, the copper installed throughout the grid is not consumed by the generation and distribution of electricity. Copper is the world's most recyclable engineering metal, and can be used and reused without losing its engineering properties like high conductivity, durability and energy efficiency.

Investment in the electrical grids and the installation of copper in them contributes to an energy-efficient and sustainable infrastructure, one that will set the standard for meeting energy needs in emerging economies throughout the world.

The Smart Grid

One aspect of the new electrical grid that receives a lot of attention is the so-called "smart grid." The Northeast blackout of August 14, 2003 brought national attention to the vulnerability of the existing electric grid. It serves as a case study on how a relatively minor grid disturbance cascaded into one of the largest blackouts in history [2]. Since then, the nationwide grid has been developed to recognize such distress and respond more quickly. These improvements require an investment in electrical equipment and switches in every part of the grid.



Generally speaking, the grid is becoming more active. Internet connectivity and big data allow smart grid and microgrid operators to better predict electrical supply and demand. When a natural outage does occur due to a weather event, a wayward branch or an act of sabotage, the smart grid can quickly respond and provide electricity where it is needed to balance the grid intelligently.

Much research on the smart grid is coordinated on the national level, but the resulting standards and best practices reverberate through to local stakeholders, including local governments as well as producers and users of electricity. The following definition of smart grid is given by the U.S. Department of Energy (DOE) [3].

“Smart grid” generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers -- mostly seen in big improvements in energy efficiency on the electricity grid and in the energy users' homes and offices.

Categories of Microgrids

The term “microgrid” has a meaning that is distinct from “smart grid,” though the two are inextricably woven together. Microgrids are certainly on the rise as communities and factories seek to become independent from the larger grid. Such independence can save on energy costs and ensure reliability as well as improve power quality and harness ecofriendly DERs.

Microgrids have been in existence since the earliest decades of electrical generation. Yet modern microgrids are entering an era of rapid development and evolution. Microgrids today take on

many different configurations, depending on the application and benefits sought. The main categories are as follows:

- I Large microgrids that exchange power with the grid;
- II Community and residential microgrids that use a combination of renewables and energy storage; and
- III Remote and isolated communities that use a combination of conventional generation (e.g., diesel generators) and renewable generation.

The first category includes urban areas, university campuses and institutions such as research centers and hospitals. The Microgrid Team at Berkeley Lab studies adoption patterns of microgrid technology and is an excellent resource for case studies of the first category [4].

One example of the first category of microgrids is the installation at the Illinois Institute of Technology (IIT) in Chicago. The peak load of the campus is around 10 megawatt (MW) and its on-campus DER includes two 4 MW combined cycle gas units and a small wind turbine. There are also plans to add rooftop photovoltaics (PV) as well as a 500 kilowatt hour (kWh) battery, which will bring the total DER capacity close to 9 MW. This will allow the campus to operate as an “island” most of the time, meaning it will not import any power from the grid. Full “islanding” capability has been tested. Furthermore, the campus is located near Comiskey Park (where the Chicago White Sox play) and IIT is involved in a load reduction program during baseball games for which it will receive significant payments [5].

The Resilience of Microgrids

The definition of a microgrid has expanded in recent years to take into account many stakeholders, including diverse communities, energy consumers, energy producers and regulatory bodies. According to the DOE, “Microgrids are localized grids that can disconnect from the traditional grid to operate autonomously. Because they are able to operate while the main grid is down, microgrids can strengthen grid resilience and help mitigate grid disturbances as well as function as a grid resource for faster system response and recovery.” [6]

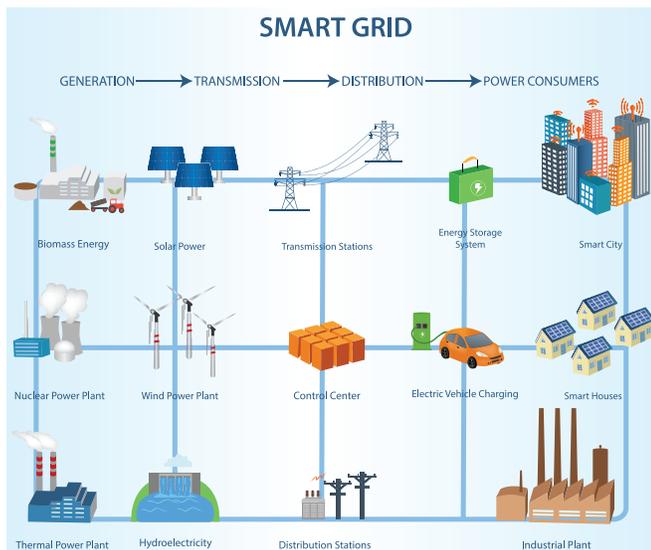
The resilience of a microgrid-based electrical infrastructure has parallels with the earliest conception of the internet during the Cold War era as a project managed by the Defense Advanced Research Projects Agency (DARPA). At that time, the internet was envisioned as a decentralized communications system. Such a network cannot easily be disrupted because its command center does not reside in any one location.

The first category of microgrids includes critical infrastructure such as military bases or hospital facilities. An example is the Fort Carson military base in Colorado Springs, Colorado, which is one of several microgrids operated by the SPIDERS (Smart

Power Infrastructure Demonstration for Energy Reliability and Security) program. This large military base has about 14,000 residents and covers 550 square kilometers. Assets include a one megawatt MW PV array and three diesel generators with a total power of 3 MW. The base as a whole has an ambitious plan to become a net zero facility using huge PV resources, potentially over 100 MW, as well as wind, ground-source heat pumps, biomass and solar water heating. [7]

Making the Connection

Recently, the National Electrical Manufacturers Association (NEMA) has provided a timely, up-to-date primer on microgrids [8]. While examining the many nuances of these systems, the report gives a definition that clearly emphasizes the close relationship between microgrids and the smart grid as follows: "A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single, controllable entity with respect to the grid."



The new electrical infrastructure will be more secure, more reliable and more energy-efficient than ever before. And there is no doubt that it will use plenty of copper. More copper will be required for use in equipment such as:

- switching and monitoring of electrical loads, which will be digitally controlled to balance supply and demand in real time;
- collecting power from many DERs, decentralizing the generation of power and creating virtual power plants (VPPs); and
- in energy storage systems, which will allow for time-shifting and peak shaving of electrical supply and demand.

The establishment of a network of microgrids requires special equipment and technology to aggregate electrical energy from interconnected DERs, to distribute that energy back into the microgrid, to upload excess energy to the grid, and so forth.

The NEMA report cited above estimates equipment costs for a typical 5 MW multi-DER installation. It classifies the equipment into two categories: microgrid isolation and stability controls; and distribution automation (two circuits: non-interruptible + critical load and non-critical load). According to the report, the first category includes a main transfer switch, a master controller and switchgear with costs ranging from \$200,000 to \$1 million. The second category includes sectionalizing switchgear, remote switchgear control, automatic fault protection and smart meters with costs ranging from \$280,000 to \$535,000.

Renewable Energy and Energy Storage



As microgrids become more ubiquitous, the technology will advance and the costs of components will drop. One can look ahead toward 2030 and envision a very different grid than the one existing today. Two rapidly developing technologies that are bound to dramatically influence the microgrid landscape are renewable energy sources and energy storage.

Currently only eight percent of the microgrid generation capacity in the U.S. is from renewables, including solar, wind, fuel cells and hydropower [8]. As microgrids are seamlessly integrated into the larger grid, renewables will become more practical. They will allow for excess wind power and solar power generated by remote communities to be shared over broader geographical regions and to ultimately make up a larger fraction of total electrical generation. Energy storage systems further will allow for alternative energy resources to be shared across temporal boundaries, evening out the daily fluctuations in the energy supply and mitigating price volatility.

One of the biggest challenges of larger utilities is how to quickly adjust to these changes in supply and demand when they may literally be dependent on which way the wind blows or the passing of a cloud overhead. A large power plant cannot simply be turned on and off like a light switch to provide needed energy on short notice to a microgrid that is highly dependent on renewables. Hence it will be advantageous for owners of microgrids to install an optimal balance of renewables and energy storage to operate efficiently within the infrastructure of the broader electric grid. Regulations will play a key role in leveling the playing field for all energy suppliers and end-users.

The Clean Coalition (Menlo Park, California) provides case studies of microgrids of the second type, that is, community

level microgrids with a high level of renewables and energy storage [9].

One such project is the Long Island Community Microgrid Project, in East Hampton, New York, which aims to achieve nearly 50 percent of its grid-area electric power requirements from local solar. The energy system will combine up to 15 MW of solar power with a 25-megawatt-hour (mWh) energy storage system. The installation will serve as a model for clean, affordable and reliable power [10].

Another microgrid project of the second type is underway in collaboration with Pacific Gas & Electric in the Bayview and Hunters Point areas of San Francisco. This world-class community microgrid showcases how a utility can deploy local renewables to benefit its customers and demonstrates that the technologies and methodologies required to deploy community microgrids are readily available today [11].

Remote Communities

Microgrids can exist completely off the grid in remote locations. A microgrid of the third type is exemplified by the island of Ta'u in American Samoa. According to a recent article by the *United Press International* (UPI), the island now generates and stores nearly 100 percent of its electricity using a large solar panel array, microgrid and batteries installed by SolarCity and Tesla. The solar-powered microgrid is managed by the American Samoa Power Authority. As much as 6 MW hours of extra solar energy can be stored in 60 Tesla Powerpacks and used at night. The new microgrid will replace 109,500 gallons of diesel per year on Ta'u. Solar energy is not only cleaner but also significantly cheaper than diesel power for islands like Ta'u, which is located 4,000 miles from the U.S. West Coast. Shipping diesel to such islands is expensive and unreliable compared to generating the electricity from the sun. [12].

Conclusion

The U.S. is well on its way to developing an electric grid that will allow for the country to have a bountiful supply of energy for years to come. The new electric grid will be built around thousands of microgrids that are not totally independent but rather can share their resources to mutual advantage while at the same time not becoming too vulnerable to a single control center.

Modern digital electronics and specialized electrical devices along with copper cables, busbars, transformers and switchgear will be an integral part of this investment in the future of America. The technology developed here in the U.S. will also set a standard for the clean energy future of Earth.

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