Journal of Undergraduate Research 9, 8-11 (2016)

Combined Heat & Powers Role in Modern Grid System

Junyan Jiang

University of Illinois at Chicago, Chicago, IL

The 21st century needs a modern grid to meet increasingly higher standards in grid efficiency, reliability, security, power quality and environmental impact. Conventional coal-fired power plants, as the major electricity power house, are being phased out due to more stringent environmental regulations. However the electricity demand still persists. Combined heat and power (CHP) as a decentralized power generation system can support the transition and formation of the modern grid because of its high efficiency, enhanced system resiliency, improved power quality, reduced cost and carbon emissions, and its fast response complimentary to intermittent renewable energy. A case study was incorporated to demonstrate CHP’s indispensable role in a modern grid configuration.

Introduction

Combined Heat & Power (CHP), also often called cogeneration, generates electricity and heat in an integrated system where thermal energy is captured and utilized for other applications. CHP is today the most efficient way of generating power. With more stringent environmental regulations to reduce carbon emissions as well as governments ambitious goal to install additional 40 GW CHP capacities by 2020, CHP as a reliable source of distributed power generation will be indispensable in a modern grid system. A modern grid refers to a reliable, resilient, secure, and environmentally responsible with consistent power quality and high efficiency grid system.

Status quo

As conventional coal-fired power plants are phasing out and the infrastructure of transmission and distribution is aging, the grid demands modernization. Based on the U.S. Energy Information Administration (EIA)’s statistics, it is shown that the planned coal-fired power plant retirements continue to increase. (Figure 1) Given the need to comply with the Environmental Protection Agencies (EPA) Mercury and Air Toxics Standards (MATS) regulations, conventional coal-fired power plants are expected to be out of the picture. The continuous increase of natural gas-fired electricity generation owing to the low price caused by shale gas glut as well as the ever-increasing amount of renewable energy will help shape the future of the grid.

The transmission and distribution infrastructure needs upgrading as well. It is estimated that approximately 70% of transformers and transmission lines are over 25 years and more than 60% of distribution poles were installed 40 to 70 years, which are all approaching the end of their useful life.1

CHP’s role in the transition & formation of modern grid

CHP as a form of decentralized power generation enjoys high efficiency, wide flexibility and reduced carbon emissions. CHP is a great alternative to avoid building large power plants. CHP systems can operate at the combined cycle efficiencies from a minimum of 55% to over 85%,3 whereas the electric generating efficiency of a conventional power plant is around 36% since the thermal energy is completely wasted. CHP can provide a wide range of capacity from one kilowatt to hundreds of megawatts in various applications including industrial manufacturers, institutions, commercial buildings, and municipal and residential developments. CHP can adopt different fuel sources not limited to natural gas, biomass, biogas or a combination of previous three. CHP can reduce the carbon emissions by almost half of the conventional generation. (Figure 2)

A strategically well-sited CHP plant can improve system resilience and power quality. CHP largely powered by natural gas can generate electricity independently off the grid in the case of catastrophes or power outages caused by grid failures. Furthermore the U.S. Energy Information Administration (EIA) estimates that electricity transmission and distribution averagely losses about 6% of the electricity that is transmitted and distributed annually in the United States.4 Having an on-site CHP

FIG. 1: Scheduled 2015 capacity additions mostly wind and natural gas; retire mostly coal. Taken from 2.
plant can significantly avert or mitigate the transmission and distribution power line losses especially during the peak load when the utility power line losses increase exponentially.

CHP can receive its permit and be built much faster than large power plants. A major centralized power plant and transmission line usually undergo a long process of decision-making, land acquisition, design and contracting before being built. A large power plant is also usually constrained in site selection as it requires a large amount of water to cool the system. Unlike large power plants, CHP is not limited to its location. In this regard, CHP can reduce the investment risk and expedite the development schedule substantially.

CHPs fast response can address the intermittent issue of renewable energy like wind and solar. CHP can ramp up and down rapidly. This feature can be utilized to generate electricity when wind and solar resources are not available. Such application can be very practical in a microgrid deployment. (Microgrids are modern, localized and small-scale grids compared to the conventional grid with centralized power generation.) Microgrids can connect and disconnect from the centralized grid and operate autonomously which can improve the grid safety and resilience tremendously. A case study will be demonstrated about the function of CHP in a form of the modern grid - microgrid.

Moreover from an economic perspective for utility companies, a well-located decentralized CHP plant can prevent or at least reduce transmission and distribution investment. A conventional centralized power plant requires building new and/or upgrading existing transmission and distribution system. Also for individual facilities, owning a CHP can alleviate the peak load which in return will save marginal utility cost and demand charge.

**Challenges CHP faced with**

CHP is still faced with a few challenges - unfavorable policies for utilities and high capital cost for individual facilities. Favorable policy, incentives, subsidies and reciprocal business models become crucial in promoting CHP in the modern grid system to realize a win-win scenario for CHP customers, utility companies and ratepayers.

Although every states policy differs, we divide the electric markets into two categories - regulated and deregulated. For the regulated market, utility companies generally can integrate CHP in their rate base and are fully allowed to enjoy the high efficiency of CHPs although they may have to account for all the risks. On the other hand in the deregulated market, electric distribution utilities cannot own power generation assets, which poses a barrier that prevents utilities from fully utilizing CHP plants.

In most deregulated markets, distribution utilities have contracts with third party CHP owners and only run CHPs during peak load as a contingency plan whereas utilities cannot fully benefit from CHPs high efficiency and third parties do not get high standby rates. If the policymakers can take all the CHPs benefits including high energy efficiency, environmental endeavor, and diminished transmission and distribution costs into consideration and promulgate favorable policies for larger deployment of CHP, all the parties involved can truly benefit from CHP.

For individual facilities, it is understandable that business owners are apprehensive about investing high capital cost in energy generation equipment rather than the core business they are familiar with. However ancillary services to sell excessive electricity and opportunities to sell surplus thermal energy to neighboring facilities could be very persuasive for individual facilities to own CHP plants. For example Princeton University gets paid back for its CHP electricity generation at about $600,000 per MW annually for its participation in PJMs ancillary services market. And the Great River Energy Spiritwood Station in Jamestown, ND CHP project successfully supplies steam to Cargill Malt plant and the Dakota Spirit AgEnergy biorefinery maximizing the overall efficiency to offset the operational cost.

An even better business model for individual facilities is having electric and/or natural gas utility companies make the initial capital investment and charge the consumer a fee each month. An example is University of Wisconsin, Madison West Campus Cogeneration Facility, a 150 MW natural gas-fired facility which provides the electricity to Madison Gas and Electric (MGE) customers and steam and chilled water to the UW-Madison campus. MGE owns the electric production part of assets while UW-Madison owns the steam heat and chilled-water assets. Such agreement was reached so that the campus, utility and ratepayers could all enjoy the high efficiency and economy of CHP.

![FIG. 2: Combined heat and power configurations. Adapted from 3.](image-url)
A case study of CHPs role in Princeton University - Microgrid

Princeton University's Microgrid configuration is composed of a CHP plant with a gas-turbine power generator, solar panel field, thermal storage (chill water), delivery network and smart control. (Figure 3) The CHP plant was constructed in 1996 which replaced the old coal-fired boilers and was awarded the Energy Star CHP Award in the following year. It is capable of producing electricity up to 15 megawatts and steam which is used for heat, hot water, sterilization, heating and cooling for roughly 180 campus buildings. Its overall efficiency is around 75% to 85%.  

Most electricity on the campus is generated by the CHP plant. The solar panel field contributes 5.5% of total power generation. The chilled water energy storage gives the option to offset the peak load by making chilled water at night and consuming it during the day.

According to EPA, Princeton University’s CHP system requires 20% less fuel than typical purchased electricity and onsite thermal generation, reducing carbon emissions by an estimated 28,000 tons annually.

An advanced real-time dispatch system as a means of smart control is utilized to determine the most cost effective way for Princeton University to supply electricity whether to generate it onsite or purchase it from the utility company. When campus demand is high and power is expensive, the campus generates the electricity itself and when at night the demand is low and electricity is cheaper to purchase than generate, the campus draws more power from the utility grid.

Princeton University participated in PJM’s ancillary services market in New Jersey’s deregulated market in 2013. The system became dispatchable directly by PJM but campus operators can still override at any time. The campus can sell electricity back to the grid.

In the event of Hurricane Sandy struck New Jersey, the Princeton area was blacked out for two days. However with the microgrid configuration, Princeton University was able to go off grid and served as a safe harbor for many. The CHP generated 13 megawatts and powered the campus until the grid went back on. After all, the heart of the Princeton microgrid configuration is the CHP plant.

It is the CHP plant that enables the campus to enjoy high efficiency, decrease carbon emissions, incorporate intermittent renewable energy use, improve grid resilience, and optimize operational cost.

Conclusion

The 21st century needs a modern grid. A modern grid will be more reliable, secure, economical, efficient, and environmentally friendly so that it can continuously serve as the backbone of our national economy. With the globally enforced mitigation of climate change, large scale coal-fired power plants will eventually be superseded.

CHP as a decentralized power generation means has gained more and more recognition of its great value. The dCHPP (CHP Policies and Incentives Database) provided by EPA is an online database to search for CHP policies and incentives by state or at federal level. It is a government initiative to promote CHP.  

CHP with numerous benefits plays a critical role in the transition and formation of the modern grid system. It can improve the overall efficiency, reduce carbon emissions and strengthen the reliability and resilience of the modern grid.

CHP as distributed power generation can synergize the formation of microgrid, a modern, independent yet interconnected grid system. It can leverage the modern grid to incorporate more renewable energy and energy storage. CHP will ultimately underpin the modern grid.

---


