Natural Gas Pipeline Systems: Delivering Resiliency

The U.S. economy depends on the reliable delivery of energy. Part of the resiliency of our national energy system is supplied by fuel diversity. Ensuring that each economic sector avoids over-reliance on any single energy source, or delivery system, is in in itself a strategy for enhancing overall system resiliency. Multiple energy systems have important roles to play. At the same time, the degree of system resilience varies between energy sectors. Where practicable, policies at all levels of government should seek to enhance the role of systems that offer greater overall resilience because of inherent characteristics like adaptability to local disruptions, and tolerance for extreme events. This paper presents a description of the key attributes that help make our nation's natural gas delivery system one of the most resilient energy delivery systems in the world.

Natural gas transmission and distribution systems possess a number of attributes that make them inherently resilient, in particular in comparison to electrical systems. Between 2008 and 2013, over 75 million customers have been affected by weather related power outages.[1] In 2011, fewer than 100,000 natural gas customers nationally experienced disruptions, while 27.3 million Americans experienced power outages. Storm-related power outages cost the U.S. economy between $20 billion and $55 billion annually.[9] Because natural gas pipelines are predominantly underground and the system more protected from the elements, natural gas systems are far more resilient in the face of extreme weather events than electrical systems.

A recent MIT report noted the inherent resilience of the national natural gas transmission and distribution system:

> The natural gas network has few single points of failure that can lead to a system-wide propagating failure. There are a large number of wells, storage is relatively widespread, the transmission system can continue to operate at high pressure even with the failure of half of the compressors, and the distribution network can run unattended and without power. This is in contrast to the electricity grid, which has, by comparison, few generating points, requires oversight to balance load and demand on a tight timescale, and has a transmission and distribution network that is vulnerable to single point, cascading failures.[3]

Overview of Natural Gas Delivery Systems. The United States possesses an extensive infrastructure for the transmission and distribution of natural gas. In total, there are 2.4 million miles natural gas pipelines in the country. For comparison, the total number of paved roads in the United States, from interstates to country lanes, is 2.7 million miles. The natural gas utility industry invests over $19 billion annually on efforts to maintain safety and reliability, and in so doing increasing the resiliency of its systems.

Of this total, 300,000 lines are dedicated to transmission. These are the underground "highways" of the natural gas delivery system. The 2.1 million miles that make up the balance of the system are dedicated to distribution. These pipelines can be thought of as the "main streets" and "neighborhood streets" of the natural gas distribution system. These pipelines are composed of different materials in different locations, including plastics, composites, coated steel, bare steel, and cast iron. All are buried three feet or more below ground.

The extensive natural gas system serves more than 71 million residential, commercial and industrial customers in the United States. The infrastructure contains more than 5,000 supply receipt points, 11,000 delivery points and 1,400 interstate interconnection points. There are 49 international import/export locations, 400 underground storage units and 113 active Liquefied Natural Gas (LNG) import facilities. Over 1,300 local distribution companies deliver natural gas to the people of the United States.

Gathering lines are low pressure pipelines, 2 to 10 inches in diameter, and are buried approximately 3 feet below the surface. Interstate pipelines consist of 20-42 inch in diameter lines and are pressurized up to 1,500 psi. Once supply exits the interstate system, the local utility customizes the gas pressure from .25 up to 200 psi to meet the adjacent service territory requirements. Distribution lines have diameters ranging from less than one inch to 24 inches.

Natural gas transmission and distribution is highly regulated by Federal and state authorities. At the Federal level, the agency with primary authority over natural gas pipeline safety is the Pipelines and Hazardous Materials Safety Administration (PHMSA) within the U.S. Department of Transportation. At the state level, natural gas distribution systems are regulated by public service or public utility commissions. These commissions are economic regulators who balance investments in system maintenance, upgrades, and expansions with an obligation to provide fair and reasonable rates to consumers.

The natural gas delivery system operates twenty-four hours per day, seven days a week. It delivers, on average, 70 billion cubic feet of natural gas to U.S. consumers each day. It is a highly elastic system, with the proven capability to deliver up to 139 billion cubic feet in a single day.

Interruptions affecting natural gas delivery systems are relatively rare and typically short in duration. A number of attributes contribute to the comparatively high resilience of natural gas systems compared to electric systems. These include:

- The physical construction of the pipeline system is not subject to the dynamic found in electrical systems where local disruptions can result in cascading disruptions throughout larger portions of the system.
- Supply redundancy due to multiple interconnecting pipeline points reinforces system integrity.
- The predominant use of compressor units that run on natural gas rather than electricity, ensuring the system's ability to move supply even during power outages.
- The extensive national network of physical storage of natural gas to ensures supply availability.
- Because they are predominantly buried underground, natural gas systems have comparatively low susceptibility to interruptions caused by weather events, in all but the most extreme natural disasters.

Redundant Systems Enhance Resilience. The U.S. natural gas infrastructure has an advantageous redundancy of interconnections for receipt and delivery of natural gas, combined with a network of compressor stations and strategically placed storage facilities. Traditionally, supply has moved via interstate pipelines from the Gulf of Mexico, from the South Central States and from the Intermountain regions to communities throughout the United States. In recent years, shale gas in the Northeast and upper Midwest have added to supply redundancy. Ongoing investments in transmission and realignment of existing pipeline of existing pipeline assets will continue to improve the overall system resiliency given the relatively new geographic distribution of natural gas production.

The interconnectedness of the pipelines also offers a great deal of flexibility in moving gas, especially during times of localized supply curtailment.

Resiliency from Compression. The United States has over 1,400 compression stations located every 50 to 100 miles along interstate pipelines to boost the pressure that is lost through the friction of the natural gas moving through the steel pipe. Natural gas moves through the transmission system at up to 30 miles per hour. Gas compressors are built on either reciprocating or centrifugal technologies and with either combustion- powered or electric-powered-drive driver technologies. Combustion driven compression historically has used gas provided by a pipeline and thereby has offered a significant level of self-sufficiency for pipeline operations.

Approximately 50 percent of compressors on transmission lines consume natural gas from the pipeline it serves. While electric motor compressors are comingled among gas consuming compressors, if no backup electrical power is available, pressure in each line will hold and reinforce regional supply redundancy.

Storage Capacity. Storage acts as a supply cushion which accommodates the fluctuation between supply production and market consumption, balancing operational needs and potential supply disruptions without affecting consumers. By pulling natural gas from storage capacity, the system has the elasticity to provide far greater quantities of natural gas than the average delivery rate. The remarkable extent of this capacity was illustrated on January 7, 2014, when the polar vortex weather event pushed demand for natural gas to record levels. Because of the widespread effects of this weather system across the country, the total delivered gas nationwide reached 139 Bcf in a single day. Natural gas distribution companies were able to absorb the enormous swing in demand in large part due to their ability to draw from storage capacity built into their systems – the results of decades of planning and investment.

Improving Risk Awareness. Public safety is the number one priority for all natural gas pipeline companies and operators. Excavation near existing pipelines is the leading reason for pipeline ruptures and service outages. Utility sponsored education campaigns, such as *Call 911* and *Think Before You Dig*, are important in addressing and preventing excavation damage. In the event that third-party, excavation-related disruptions do occur, natural gas companies are able to respond to and resolve these ruptures in a timely manner. As noted previously, due to the multiple redundancies built into natural gas transmission and distribution systems, these events are isolated to small geographical area and do not cascade into regional outages.

Lower Vulnerability to Natural Disasters. Unlike the power grid, the natural gas infrastructure is underground and exposed to fewer potential natural disasters. Electric delivery systems are susceptible to damage from a wide array of events (including rain and lightning, high winds, dust storms, hurricanes, and wildfires) that do not impact natural gas systems.

The principle category of natural disaster likely to affect natural gas systems is earthquakes. Both electrical systems and natural gas systems can be damaged by earthquakes. Rare pipeline damage caused by earthquakes occurs because of large scale soil displacement rather than ground shaking. Typically, only earthquakes rated at 7.5 or higher on the Ritcher Scale are likely to sever natural gas pipelines.[4]

The 1994 Northridge California earthquake is considered one of the worst earthquakes for natural gas disruption in history. All told it caused an estimated $20 billion in damage making it one of the costliest natural disasters in U.S. history. Approximately 120,000 people had natural gas service interrupted due to the effects of the main shock and subsequent aftershocks.[5] Compared to 2,500,000 customers who lost electric service, the natural gas infrastructure demonstrated its relative strength and resiliency.[6]

Moreover, natural gas pipelines in more recent years are typically made of high-strength steel or polyethylene plastic materials, which have greater flexibility and improved likelihood to withstand significant earth movement without sustaining damage.

Opportunities to Further Improve Resiliency. While our national transmission and distribution system for natural gas has many existing characteristics that ensure a high degree of overall resiliency, there are a number of policy measures that could enable and encourage further investments in the system to improve our national energy resiliency to even greater levels. Some of these opportunities entail leveraging the inherent resiliency of natural gas systems to improve the resilience of electric systems.

For example, policies to encourage greater use of combined heat and power (CHP), as well as micro-grids and distributed generation powered by fuel cells, could alleviate demand pressures on centralized electrical generation while providing superior reliability for electric customers served by these installations. The recent experience of communities devastated by Hurricane Sandy, and the value provided by natural gas supplied fuel cell banks for back-up power at hospitals and other buildings, demonstrates the value of this approach.

Policies to encourage natural gas system expansion to unserved or under-served areas would also offer the opportunities for more Americans to benefit from the resilience and reliability of natural gas systems. Rate structures that encourage additional investment in storage, by natural gas utilities and perhaps for natural gas fired electrical generation, could also provide system-wide benefits.

Perhaps the greatest opportunity to improve the overall energy resilience of the nation lies in developing policies that ensure better coordination between natural gas and electric systems. As described earlier, natural gas systems are largely decoupled from power outages and continue to be able to deliver to their customers reliably even when electrical systems are down. However, as electric generation from natural gas rises, electric system resiliency will increasingly depend on how well electric markets provide the right economic signals for natural gas companies to invest in infrastructure needed to serve gas-fired generators.

References

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