VIRGINIA ACADEMY *of* SCIENCE, ENGINEERING, AND MEDICINE

WHITE PAPER

TECHNOLOGIES FOR POWERING VIRGINIA'S DATA CENTERS

WRITTEN IN RESPONSE TO A REQUEST FOR TECHNICAL ANALYSIS FROM VIRGINIA DELEGATE DAVID REID

Virginia Academy of Science, Engineering, and Medicine

September 2024

Technologies for Powering Virginia's Data Centers

Executive Summary

In July 2024, David Reid, delegate from Loudoun County, asked the Virginia Academy of Science, Engineering, and Medicine (VASEM) to provide "brief, unbiased, nonvested-interest scientific and engineering assessments" of a series technologies being proposed to preserve Loudon County's place as the preeminent location for data centers in the world. Northern Virginia, the single largest data center market anywhere by total power consumed.[1] houses almost half of the data centers in the United States, and Loudon County, with over 230 data centers, is at its epicenter.

A principal challenge facing Loudoun County is sourcing the energy needed to support the construction of a new generation of data centers with the capacity to supply the computational power required by artificial intelligence and other uses. In 2024, it was not uncommon to see power purchase agreements (PPAs) signed for 200, 300, or 400 megawatts (MW) for new developments. Dominion and Northern Virginia Electric Cooperative (NOVEC) have seen larger data center campuses emerging that are requesting between 300 MW to several gigawatts of power.

The amount of electric power demand that data centers now require is eye-opening. Dominion Energy conservatively estimates that one megawatt of power can provide electricity to 250 homes. Using this rule of thumb, 300 MW would power 75,000 homes. For comparison, the most recent nuclear reactor to enter service in the United States, Vogtle Unit 4 commissioned in March 2024, generates 1,114 MW.

Del. Reid noted that "some organizations [proposing solutions to data center energy needs] are portraying engineering concepts as proven existing capabilities. For those of us who are not engineers or scientists but who are responsible for making informed policymaking decisions, this causes confusion and unnecessary distractions from identifying realistic, workable solutions."

He asked VASEM to provide "ground truth" on three technologies that he said have been frequently invoked to meet Loudoun County's energy needs: small modular reactors (SMRs), advanced conductor materials (ACMs) and high voltage direct current (HVDC) transmission. For each technology, Del. Reid listed a series of claims that he asked VASEM to investigate.

[1] Sources can be found in the body of the report.

VASEM responded by assembling a panel of experts to provide a technical appraisal of each technology and its potential role in addressing Loudoun County's looming energy shortage. They included:

- James Aylor, former chair of the Electrical and Computer Engineering Department at the University of Virginia (UVA) and dean emeritus of its School of Engineering and Applied Science. He is a fellow of the Institute of Electrical and Electronic Engineers (IEEE).
- Robert Carritte, former principal officer of MPR Associates, a worldwide leader in nuclear engineering, fuels, and deployment solutions.
- Chen-Ching Liu, American Electric Power Professor and director, Power and Energy Center, at Virginia Tech. He is a fellow of the IEEE and a member of the National Academy of Engineering.
- Matthew Gardner, vice president of planning and operations (electric transmission) at Dominion Energy, president-elect of CIGRE—United States National Committee.
- Damir Novosel, president and founder of Quanta Technology, a technical consulting and advisory services company specializing in the electric power and energy industries. He is a member of the National Academy of Engineering and a fellow of the IEEE.
- Harry Powell, professor emeritus, electrical and computer engineering, at UVA.
- David Roop, former director of electric transmission operations in the Power Delivery Group at Dominion Energy. He is a member of the National Academy of Engineering and serves on its Energy Working Group.

The panel's findings are as follows:

Small Modular Reactors: Issues Raised by Del. Reid

- **These have been portrayed as proven technologies, ready for deployment**. There are over 80 different SMR designs under development. They cannot be deployed until they are approved by the Nuclear Regulatory Commission (NRC). Currently, only one SMR, NuScale's VOYGR SMR, has received approval, although others are in the pipeline. In addition, there are no facilities capable of producing the enriched fuel that they require. The NRC is working to streamline the approval process, and the U.S. Department of Energy is pursuing several pathways to secure a domestic supply of high-assay low-enriched uranium (HALEU). It is unlikely that commercial SMRs will be deployed in a significant way until the 2030s.
- **It has been stated that SMRs have no blast zone, they will not melt down, they require no maintenance.** The safety record for the existing operating reactors in the United States is extremely high. SMRs and other advanced reactors under development employ accident tolerant fuel designs and rely on a variety of passive safety features. This will make them inherently safer than today's commercial light-water reactors. However, these systems must be certified by the NRC prior to deployment.
- **SMRs have been proposed to power local micro-grids, where data centers are co-located in communities with dense housing developments**. Co-locating SMRS at data centers or placing them in urban or suburban locations would entail major savings in time and capital

resources. While they are safer than traditional reactors, most proposals to co-locate SMRs at data centers (like the Surry Green Energy Center) are typically for sites in rural areas.

- **Some vendors have stated they have 30+ "contracts" for their SMRs.** There is tremendous interested in SMRs and other advanced reactor technologies among traditional utility customers and energy-intensive industrial companies. However, outside of seed-money investments and numerous memoranda of understanding (MOUs) firm contracts for the construction of SMRs or advanced reactors within the United States have not materialized.

Advanced Conductor Materials: Issues Raised by Del. Reid

- **Reportedly ACMs have been used in Europe for decades**. ACMs have been deployed around the world since 2003 and in the last decade have been widely adopted in Europe. They have also been deployed in the United States.
- **It allows for 30-50% more energy to be transmitted along the same route**. There are several different kinds of ACMs, each with its own current capacity. However, they all provide at least a 50% improvement over steel core conductors.
- **I've not seen any data on the cost differential between a steel core and an ACM core**. ACM cores are more expensive, but the cost of reconductoring an existing line to transmit added power is much less than building a new one. The cost of the conductor is a small part of the cost of a new line.

High Voltage Direct Current: Issues Raised by Del. Reid

- **Can more easily be placed underground because the current does not attenuate into the ground**. Because HVDC systems do not produce a capacitive charge, they do not lose power when placed underground.
- **Is better at accepting power from renewable energy sources**. Because HVDC currents can be precisely controlled, HVDC makes it easier to regulate their flow from intermittent energy sources and deliver them to load centers where they are needed.
- **Can deliver more power from source to destination without power loss along the route**. The U.S. Department of Energy states that HVDC losses can be up to 30% to 50% lower than comparable HVAC systems.
- **Can be scaled to much higher voltages than existing 500kV AC lines.** China has completed a several ultra-high-voltage direct current 1,000 kV and 1,100 kV lines to bring energy from remote generation facilities to population centers. There are no plans to introduce them in the United States. While more efficient than HVDC lines, they face currently insurmountable technological, financial, and environmental hurdles.

In addition to examining the technologies Del. Reid specified, the panel included an analysis of two grid-enhancing technologies—dynamic line ratings and gas-insulated lines—that may be deployed in the short-term to address Loudoun County's energy challenges. There are also other issues outside the scope of this report, such as the direct impact on the transmission and distribution grids, that will affect efforts to supply electrical power to data centers.

In producing this report, VASEM's goal has not been to pass judgment on individual technologies but to quickly deliver fair, impartial, and unbiased information that would assist Del. Reid and other elected officials make informed decisions and determine where more in-depth research and study is needed. The Virginia Academy stands ready to serve a similar role for other members of the General Assembly and other branches of Virginia government with questions about technology that they need answered.

Technologies for Powering Virginia's Data Centers

Introduction

Currently, there are over 10,900 data centers worldwide—and the United States has more than 45% of them, 10 times more than each of its nearest rivals Germany, the United Kingdom, and China.[2] Northern Virginia, the single largest data center market in the world by total power consumed.[3] houses almost half of the data centers in the United States,[4] and Loudon County, with over 230 data centers, is at its epicenter.[5]

Data center campuses have grown in size and number over the last five years as the role of data centers continues to evolve and expand to include ever-more power-hungry applications. For instance, they are now used to train artificial intelligence models. its first quarter 2024 earnings report, Dominion Energy noted that typical data center power demand has grown from 30 megawatts (MW) to 60-90 MW. In 2024, it was not uncommon to see power purchase agreements (PPAs) signed for 200, 300, or 400 MW for new developments. Google set a record when it signed a PPA for over 600 MW in Texas.[6] Dominion and Northern Virginia Electric Cooperative (NOVEC) have seen larger data center campuses emerging that are requesting between 300 MW to several gigawatts of power. Such increases in power demand drives the need for new large-scale generation capacity and a need for new power transmission resources.

Seen in this context, the amount of electric power demand that data centers now require is eye-opening. Dominion Energy conservatively estimates that one megawatt of power can provide electricity to 250 homes.[7] Using this rule of thumb, 600 MW would power 150,000 homes. For comparison, the most recent nuclear reactor to enter service in the United States, Vogtle Unit 4 commissioned in March 2024, generates 1,114 MW.[8]

---

[2] Minnix, John. "115 Data Center Stats You Should Know In 2024," Brightlio - Technology Illuminated, April 22, 2024, https://brightlio.com/data-center-stats/.

[3] "2024 Global Data Center Market Comparison," n.d. https://cushwake.cld.bz/2024-Global-Data-Center-Market-Comparison.

[4] Augenstein, Neal, "Why is Northern Va. the world's data center capital?" *WTOP News*, October 25, 2022, https://wtop.com/virginia/2022/10/why-is-northern-va-becoming-the-worlds-data-center-capital/.

[5] "Virginia Data Centers," n.d. https://www.datacentermap.com/usa/virginia/#.

[6] "2024 Global Data Center Market Comparison."

[7] The U.S. government's Idaho National Laboratory uses the rule of thumb that one megawatt provides electricity to 800 homes, Dominion Energy MediaRoom. "Dominion Meets Record Winter Peak Demand for Electricity from Customers," n.d. https://news.dominionenergy.com/news?item=70848#:~:text=One%20megawatt%20supplies%20enough%20electricity,to%20all%20of%20those%20customers.

[8] "Plant Vogtle Unit 4 begins commercial operation - U.S. Energy Information Administration (EIA)," n.d. https://www.eia.gov/todayinenergy/detail.php?id=61963#:~:text=The%20two%20new%20reactors%20bring,plant%20in%20the%20United%20States.

Dominion Energy has connected 94 data centers with more than 4 GW of capacity in Northern Virginia since 2019.[9] After connecting 15 data centers with a total capacity of 933 MW in 2023, Dominion Energy expects to connect 15 additional data centers to the power grid in 2024.[10] Virginia is following a worldwide trend of building new data center clusters to outlying areas, with a growing number of centers in operation or under construction in Prince William, Culpeper, and Spotsylvania Counties as well as in the Richmond metro area. [11] Data centers made up nearly a quarter of Dominion Energy Virginia's electricity sales in 2023.[12]

A Request for Ground Truth

If Virginia—and particularly Loudoun County—is to continue its data center dominance, major capital investments in both new generation resources and transmission lines and substations will be required. Not surprisingly, there have been a stream of proposals about how this energy might be generated and transmitted. In July 2024, Del. David Reid, who represents Loudoun County in the Virginia House of Delegates, asked the Virginia Academy to provide "brief, unbiased, nonvested-interest scientific and engineering assessments on some of the technologies being proposed to address the problem." Del. Reid requested "ground truth" on three technologies that he said have been frequently invoked as having potential to help meet Loudoun County's energy needs: small modular reactors (SMRs), advanced conductor materials (ACMs) and high voltage direct current (HVDC) transmission. For each technology, Del. Reid listed a series of claims that he asked VASEM to investigate.

VASEM responded by assembling a panel of experts to provide a technical appraisal of each technology and its potential role in addressing Loudoun County's looming energy shortage. They included:

- James Aylor, former chair of the Electrical and Computer Engineering Department at the University of Virginia (UVA) and dean emeritus of its School of Engineering and Applied Science. He is a fellow of the Institute of Electrical and Electronic Engineers (IEEE).
- Robert Carritte, former principal officer of MPR Associates, a worldwide leader in nuclear engineering, fuels, and deployment solutions.
- Chen-Ching Liu, American Electric Power Professor and director, Power and Energy Center, at Virginia Tech. He is a fellow of the IEEE and a member of the National Academy of Engineering.
- Matthew Gardner, vice president of planning and operations (electric transmission) at Dominion Energy, president-elect of CIGRE—United States National Committee.

---

[9] "Q1 2024 Earnings Call," May 2, 2024, https://s2.q4cdn.com/510812146/files/doc_financials/2024/q1/2024-05-02-DE-IR-1Q-2024-earnings-call-slides-vTC.pdf.
[10] "Q1 2024 Earnings Call," May 2, 2024, https://s2.q4cdn.com/510812146/files/doc_financials/2024/q1/2024-05-02-DE-IR-1Q-2024-earnings-call-slides-vTC.pdf.
[11] "2024 Global Data Center Market Comparison."
[12] Blue, Robert M, "Powering Your Every Day 2023 Annual Report," March 7, 2024, https://s2.q4cdn.com/510812146/files/doc_downloads/2024/2024/03/21/Dominion-Energy-2023-Annual-Report-and-Annual-Report-on-Form-10-K-1.pdf.

- Damir Novosel, president and founder of Quanta Technology, a technical consulting and advisory services company specializing in the electric power and energy industries. He is a member of the National Academy of Engineering and a fellow of the IEEE.
- Harry Powell, professor emeritus, electrical and computer engineering, at UVA.
- David Roop, former director of electric transmission operations in the Power Delivery Group at Dominion Energy. He is a member of the National Academy of Engineering and serves on its Energy Working Group.

In addition to examining the technologies Del. Reid specified, the panel included an analysis of two grid-enhancing technologies—dynamic line ratings and gas-insulated lines—that may be deployed in the short-term to address Loudoun County's energy challenges. There are also other issues outside the scope of this report, such as the direct impact on the transmission and distribution grids, that will affect efforts to supply electrical power to data centers. In producing this report, VASEM's goal has not been to pass judgment on individual technologies but to quickly deliver fair, impartial, and unbiased information that would assist Del. Reid and other elected officials make informed judgments of their own.

Small Modular Reactors (SMRs)

At a Glance: Issues Raised by Del. Reid

- **These have been portrayed as proven technologies, ready for deployment**. There are over 80 different SMR designs under development. They cannot be deployed until they are approved by the Nuclear Regulatory Commission (NRC). Currently, only one SMR, NuScale's VOYGR SMR, has received approval, although others are in the pipeline, and the NRC is working to streamline the approval process. In addition, there are no facilities capable of producing the enriched fuel that they require. Consequently, it is unlikely that commercial SMRs will be deployed in a significant way until the 2030s.
- **It has been stated that SMRs have no blast zone, they will not melt down, they require no maintenance.** The safety record for the existing operating reactors in the United States is extremely high. In fact, it is better than all other forms of generation, including renewable energy. SMRs and other advanced reactors under development employ accident tolerant fuel designs and rely on a variety of passive safety features. This will make them inherently safer than today's commercial light-water reactors. However, these systems must be certified by the NRC prior to deployment.
- **SMRs have been proposed to power local micro-grids, where data centers are co-located in communities with dense housing developments**. Co-locating SMRS at data centers or placing them in urban or suburban locations would entail major savings in time and capital resources because they would minimize the need for major transmission system upgrades. While they are safer than traditional reactors, most proposals to co-locate SMRs at data centers (like the Surry Green Energy Center) are typically for sites in rural areas.

- **Some vendors have stated they have 30+ "contracts" for their SMRs.** There is tremendous interested in SMRs and other advanced reactor technologies among traditional utility customers and others, especially energy-intensive industrial companies and high technology companies who desire to reduce their carbon footprint. However, outside of seed-money investments and numerous memoranda of understanding (MOUs) firm contracts for the construction of SMRs or advanced reactors within the United States have not materialized.

Small modular reactors (SMRs) are often proposed to meet the energy needs of data centers, either sited next to existing power plants or co-located at the centers. SMRs are attractive to large data center operators because their power capacities and 24/7 availability can meet their carbon-reduction targets. SMRs also are attractive to utilities because they provide a constant carbon-free supply of power that complements intermittent renewable sources. There are, however, a number of significant milestones that must be reached before deployment of SMRs becomes a reality.

Understanding SMRs

Nuclear reactors in use in commercial power plants across the United States range in size from 519 MW at Prairie Island in Minnesota to 1,401 MW at Grand Gulf in Mississippi. All commercial nuclear reactors in service in the United States are light-water reactors (LWRs), although there are several different designs.[13] They use ordinary water to capture the heat produced when atoms are split and deliver it to systems that convert that heat into electricity. In addition, the water is used to moderate the speed of the neutrons thrown off when atoms are split so that they are more likely to split other atoms.

The International Atomic Energy Agency (IAEA) defines SMRs as advanced nuclear reactors with a power capacity of up to 300 MW, one-third the capacity of a traditional nuclear power reactors. IAEA denotes SMRs in the 1 MW to 10 MW range as microreactors.[14] Microreactors may be used for sites that are not on the grid such as remote or isolated communities or for sites that must operate even if the grid goes down, like military bases.

It is important to note that the term *SMR* is an indication of size, not reactor type and that there is no single design for SMRs. According to the IAEA, there are more than 80 commercial designs under development around the world. These designs are at different levels of technological maturity and therefore must confront different technology gaps before wide-

[13] In some reactors, heavy water, which has an extra neutron in its hydrogen atom, is used to transfer heat and moderate the reaction. In LWRs, water molecules sometimes steal a neutron from the nuclear chain reaction and incorporates it into its hydrogen atom; Because the hydrogen atoms in heavy water already have an extra neutron, they are unlikely to absorb another. As a result, it takes fewer neutrons to sustain the chain reaction. However, securing a supply of heavy water is an expensive process,

[14] IAEA, "What are Small Modular Reactors (SMRs)?," n.d. https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs#:~:text=Small%20modular%20reactors%20(SMRs)%20are,of%20traditional%20nuclear%20power%20reactors.

scale deployment. More mature concepts—small modular LWRs, small modular sodium-cooled fast reactors (SFRs), small modular high-temperature gas-cooled reactors (HTGRs)—must secure regulatory approval, resolve fuel and supply chain issues, and demonstrate operational performance. SFRs and HTGRs will need to address supply chain and high-assay low-enrichment uranium (HALEU) issues and operational reliability, which have impacted those designs in the past.

Less mature concepts—gas-cooled fast reactors (GFRs), fluoride-molten-salt-cooled high-temperature reactors (FHRs), molten-salt-fueled reactors (MSRs), and large SFRs—have technology gaps related to viability and performance of key reactor features, including fuel and materials behavior and adequacy of passive safety systems. Increased use of better-performing materials, advanced fuels and high-performance fuel cladding materials, and advanced/additive manufacturing could produce notable improvements in performance and economics.[15]

Considered as a group, the theoretical advantages of SMRs are clear. Many of the benefits of SMRs are inherently linked to the nature of their small, modular design. Given their smaller footprint, SMRs can be sited on locations not suitable for larger nuclear power plants. They can be prefabricated in a factory and then shipped and assembled on site, making them more affordable and faster to build than large power reactors, which are often custom designed for a particular location. They promise to be less capital intensive to build than large LWRs, although larger reactors may be more economical on dollar/kilowatt-hour basis because of economies of scale. Because they are modular, they can be deployed incrementally to meet increasing energy demand.

In comparison to existing reactors, proposed SMR designs are generally simpler, and their safety systems often rely on passive physical systems, such as natural circulation, convection, gravity and self-pressurization, that automatically cause the reactor to shut down in the case of an emergency without any electronic monitoring or human intervention.

These increased safety margins, in some cases, eliminate or significantly lower the potential for unsafe releases of radioactivity to the environment in case of an accident. Plant performance under worst-case design basis conditions is evaluated by the Nuclear Regulatory Commission (NRC) during the design certification and licensing process.

Getting the First SMR off the Ground

Currently, there are two SMR power plants in operation around the world, one in Russia (2020) and the other in China.[16] No SMRs have been built in the United States, and currently only one,

---

[15] *Laying the Foundation for New and Advanced Nuclear Reactors in the United States*. *National Academies Press eBooks*, 2023, https://doi.org/10.17226/26630.

[16] Dewan, Angela, Ella Nilsen, and Lou Robinson, “New-wave reactor technology could kick-start a nuclear renaissance—and the US is banking on it,” April 26, 2024, https://www.cnn.com/2024/02/01/climate/nuclear-small-modular-reactors-us-russia-china-climate-solution-intl/index.html

NuScale's light water VOYGR SMR, has been certified by the NRC.[17] As part of its announcement, the NRC highlighted its safety, noting that it "leverages natural process, such as convection and gravity, to passively cool the reactor without additional water, power or operator action."

NuScale had contracted to supply six of its 77 MW VOYGR units[18] to the Utah Associated Municipal Power Systems as part of its Carbon Free Power Project (CFPP) in Idaho. The parties abandoned this initiative in November 2023 when rising costs, particularly steel and concrete, discouraged subscriptions from customers needed to start the project.[19] One consequence of this setback is that NuScale's focus has shifted from providing clean, firm grid power to serving large energy consumers like data centers. Right before the termination of the CFPP, it signed an agreement to be the technology partner for Standard Power, which plans to use NuScale's 77 MW SMRs to provide nearly 2 gigawatts (GW) of power to future data centers in Ohio and Pennsylvania.[20]

There are other SMRs in the development pipeline. For instance, TerraPower has begun construction on its 345-MW Natrium sodium-cooled fast reactor demonstration project near Kemmerer, Wyoming, although construction activities will initially be limited to non-nuclear site features. Nuclear construction will begin after the U.S. Nuclear Regulatory Commission approves TerraPower's 2023 nuclear construction permit application, a process TerraPower's chairman, Bill Gates, said could take several years. The facility will supply power to PacifiCorp, an electric power company serving 1.8 million customers in the western United States.[21]

The Natrium is one of two awardees in the U.S. Department of Energy's Advanced Reactor Demonstration Program. X-energy 's Xe-100 reactor is the other. The Xe-100, producing 80 MW, is a high-temperature gas reactor. X-energy plans to submit a construction permit application to install four Xe-100s at a 4,700-acre Dow industrial site in Texas before the end of 2024. Construction on the four-reactor project is expected to begin in 2026 and to be

[17] Energy.gov, "NRC Certifies First U.S. Small Modular Reactor Design," n.d. https://www.energy.gov/ne/articles/nrc-certifies-first-us-small-modular-reactor-design.

[18] Light water SMR designs, which use already accepted technology, are likely to be among the first to receive NRC approval. Among those are the GE Hitachi BWRX-300, which is a smaller, simpler, and supposedly easier to build version of the GE design used for traditional reactors. The company says 80 percent of its components are already approved by the NRC. - ANS / Nuclear Newswire, "2024: The State of Advanced Reactors," n.d. https://www.ans.org/news/article-5634/2024-the-state-of-advanced-reactors/.

[19] Larry Pearl, "NuScale, UAMPS terminate small modular reactor project in Idaho," *Utility Dive*, November 9, 2023, https://www.utilitydive.com/news/nuscale-uamps-terminate-small-modular-nuclear-reactor-smr-project-idaho/699281/.

[20] Utility Dive, "NuScale CEO touts data center deal, heavy industry SMR interest amid $180M loss for 2023," March 15, 2024, https://www.utilitydive.com/news/nuscale-small-modular-reactor-smr-data-center-nuclear/710442/.

[21] "TerraPower begins construction at 345-MW advanced reactor site in Wyoming," *Utility Dive*, June 12, 2024, https://www.utilitydive.com/news/terrapower-smr-advanced-nuclear-reactor-bill-gates/718722/.

completed by the end of this decade.[22] There are also talks underway to install an Xe-100 at facilities in the United Kingdom.[23]

To-date, it has taken a substantial amount of time required for SMRs to go from application to deployment. The NRC accepted NuScale's design certification application in 2018 and certified it in 2023. The first module in the CFPP was supposed to be operational in 2029. The recent enactment of the ADVANCE Act requires the NRC to streamline the licensing process. Currently, there are two licensing processes that can lead to the deployment of SMRs. Operators following 10 CFR Part 52 file for a combined operating license that uses a certified design and early site permit. Alternatively, applicants following the regulations under 10 CFR Part 50 proceed in a two-step process. They initially apply for a construction permit to design and build a plant, then apply for a license to operate the plant. Each licensing process has distinct advantages and disadvantages. All of the nuclear plants operating in the United States, with the exception of Vogtle Units 3 and 4, followed the two-step process.

Regardless, most agreements to field uncertified SMRs should be viewed critically. They are, in effect, statements of intent. Even in the case of certified SMRs like VOYGR, SMR manufacturers have still to demonstrate a valid use case and show improved cost metrics comparable to other low-carbon power generation technologies. Those being adopted for government demonstration programs are also subject to procurement process regulations. For instance, in spring 2024, the Department of Defense placed its pilot microreactor program at Eielson Air Force Base on hold when a competitor protested the selection of Oklo as the reactor provider.

Another obstacle that must be overcome is sourcing nuclear fuel. Currently, the Russian state nuclear company produces almost all the high-assay low-enriched uranium (HALEU) fuel that SMRs require. These are more highly enriched than the fuels used by the current fleet of operating commercial reactors. The construction and licensing of new enrichment and fabrication facilities for these fuels as well as resolving other supply chain challenges are required to enable the deployment of the advance reactor technologies under development. The Energy Act of 2020 directed the Department of Energy to establish a HALEU Availability Program, and the Inflation Reduction Act of 2023 invests $700 million to support the programs activities.

The National Academy of Engineering, in its report on advanced nuclear reactors, determined that SMRs will not be deployed until the late 2020s or early 2030s.[24] This accords with the integrated resource plans (IRPs) published by numerous utilities that anticipate the deployment of SMRs in the 2030s. For instance, Duke Energy's Carolinas IRP envisions SMRs coming online in 2035.[25]

---

[22] "Dow | X-energy — X-energy," X-energy, n.d., https://x-energy.com/seadrift.
[23] "Funds awarded to assist Xe-100 deployment in the UK: New Nuclear - World Nuclear News," n.d., https://www.world-nuclear-news.org/Articles/Funds-awarded-to-assist-Xe-100-deployment-in-the-U.
[24] *Laying the Foundation for New and Advanced Nuclear Reactors in the United States.*
[25] "Chapter 3 | Portfolios," *Carolinas Resource Plan*, n.d., https://www.duke-energy.com/-/media/pdfs/our-company/carolinas-resource-plan/chapter-3-portfolios.pdf?rev=4351b5246a2f4172a93b7a019df3fcf7.

Likely Data Center Scenarios in Virginia

There are two ways that SMRs can be deployed to help meet the energy needs of data centers. First, they can be used to provide additional power to the grid. In July 2024, Dominion Energy announced that it has issued a request for proposals (RFP) from leading SMR companies to evaluate the feasibility of developing an SMR at the company's North Anna Power Station in Louisa County. Dominion made it clear that the RFP is not a commitment to build an SMR, but rather an important first step in evaluating the technology.[26] Siting the SMR at North Anna makes sense because the existing infrastructure required for nuclear power is already in place.

Second, SMRs can directly power data centers by being co-located on-site. The constraints in collocating SMRs at data centers are captured by a plan for the Surry Green Energy Center, an industrial park planned for a 641-acre site a short distance from Dominion's Surry Power Plant's two 838 MW reactors. The developers plan to eventually build 19 data centers at the site.

Low-cost land, proximity to power, access to fiber-optic networks, and local acceptance of nuclear power are all key elements in their choice of location. The operators intend to build onsite SMRs to provide energy to the data centers but acknowledge that this may not happen for a decade or more. In the meantime, they will depend on Prince George Electric Cooperative for power. Once the SMRs are delivered, they also plan to use the SMRs to generate the power to drive the electrolysis of water to produce clean hydrogen. Ultimately, they plan on installing between four and six SMRs, each capable of producing 250 MW of power.[27]

Currently, there are no credible plans to co-locate SMRs with data centers in suburban areas.

Advanced Conductor Materials (ACMs)

At a Glance: Issues Raised by Del. Reid

- **Reportedly ACMs have been used in Europe for decades**. ACMs have been deployed around the world since 2003 and in the last decade have been widely adopted in Europe. They have also been deployed in the United States.
- **It allows for 30-50% more energy to be transmitted along the same route**. ACM cores are more expensive, but the cost of reconductoring an existing line to transmit added power is much less than building a new one. The cost of the conductor is a small part of the cost of a new line.

[26] Dominion Energy MediaRoom, "Dominion Energy takes important step to determine feasibility of Small Modular Reactor (SMR) technology to support customers' needs," July 10, 2024, https://news.dominionenergy.com/2024-07-10-Dominion-Energy-takes-important-step-to-determine-feasibility-of-Small-Modular-Reactor-SMR-technology-to-support-customers-needs.

[27] Stephen Faleski, "Surry approves nuclear-powered data center campus that promises more than 1,300 jobs - Smithfield Times," Smithfield Times, February 12, 2024, https://www.smithfieldtimes.com/2024/02/12/surry-approves-nuclear-powered-data-center-campus-that-promises-more-than-1300-jobs/.

Building the number of new transmission lines required to meet the United States' burgeoning power needs is difficult. Utilities and transmission system owners face a variety of obstacles ranging from permitting delays and shortages of construction materials and experienced labor to scarcity of available land and increasing land prices. One option for utilities is to reconductor existing overhead transmission lines using advanced conductors made from composites. While advanced conductors are typically more expensive than the aluminum conductor steel reinforced (ACSR) and aluminum conductor steel supported (ACSS) conductors that have long been used for the majority of the existing U.S. grid, advanced conductor technology makes it possible to increase transmission capacity in a much shorter timeframe and for roughly one-third to one-half the cost of building new lines. For instance, some modifications to existing transmission structures or substations to accommodate increased power flows may be required, depending on the advanced conductor used, but these modifications are quicker and cheaper than new construction.

Advanced conductors have been the subject of two authoritative reports in the past year, one published by the Idaho National Laboratories[28] and the other jointly by the University of California Berkeley and GridLab.[29] Much of the information in this section is based on these references.

Steel Core Conductors

ASCR conductors feature strands of hardened conductive aluminum wrapped around a galvanized steel core, a basic design that has been used for more than a century. Modern ACSR conductors are designed to operate at continuous temperatures of up to 93°C (200°F) without being damaged and at even higher temperatures for brief periods during emergency conditions. At these high temperatures, the steel and aluminum expand, which causes the conductors to sag closer to the ground. Consequently, transmission lines are limited in the amount of current based on their tolerance for sag.

To address these limitations, ACSS conductors were introduced in the 1970s. ACSS is much like ACSR except it uses fully annealed aluminum to withstand higher operating temperatures and a higher temperature zinc/aluminum coating around the steel core. ACSS costs at most 20% more than ACSR but offers approximately twice the capacity at its maximum operating temperature of 250°C.

However, operation at higher temperatures runs the risk of excessive sag due to the high thermal expansion of steel. This drawback restricts the applicability of ACSS, necessitating taller structures or shorter spans in new lines to accommodate prescribed minimum clearances. In

[28] "Advanced Conductor Scan Report, Revision 1," United States of America: Idaho National Laboratory, April 2024, https://inl.gov/content/uploads/2024/02/23-50856_R8_-AdvConductorszScan-Report.pdf.
[29] Emilia Chojkiewicz et al., "Reconductoring with Advanced Conductors Can Accelerate the Rapid Transmission Expansion Required for a Clean Grid," 2021, https://www.2035report.com/wp-content/uploads/2024/04/GridLab_2035-Reconductoring-Technical-Report.pdf.

the last few decades, ACSS technology has improved by using trapezoidal stranding for the aluminum conductor (ACSS-TW) and a variety of coatings to improve performance.

During their long history, a comprehensive set of standards has been established for the production and deployment of ACSR and ACSS conductors. Line design engineers and line workers have experience with these two types of conductors, which have proven themselves over many thousands of miles.

Advanced Conductor Materials

Progress in materials science has led, in recent years, to the development of advanced conductors using ceramic, glass, or carbon fiber composite matrix materials. These composite-core conductors sag less at high temperatures than steel-core conductor, hence are known as high temperature low sag conductors. Because composite cores are less dense than steel cores of comparable strength, they can accommodate additional aluminum strands without adding to their diameter.

There are a number of composite core technologies on the market. The first, the aluminum conductor composite reinforced (ACCR) conductor was introduced in 2002. The core is composed of aluminum oxide ceramic fibers embedded in an aluminum matrix. Ceramic fibers have half the density and thermal expansion coefficient of steel cores and sag much less. ACCR can be used at temperatures of up to 210°C and can carry double the current of ACSR technologies. Its main drawback is its very high cost and special handling requirements.

The aluminum conductor composite core (ACCC) conductor was introduced in 2005 and is the most widely deployed composite-core technology, having been installed in 1,100 projects worldwide. Its composite core is composed of carbon and glass fiber embedded in a thermoset epoxy matrix. While 2.5 to 3.0 times the cost of ACSR, it has the advantages of higher capacity, less sag, and lower weight. This makes ACCC ideal for reconductoring because it may require less tower reconditioning.

The last decade has seen the introduction of several new composite conductors, including one manufactured by TS Conductor, with a core composed of carbon fiber embedded in a thermoset epoxy matrix and encapsulated with an aluminum tube, and the C7 conductor commercialized in 2014 by Southwire. It has a stranded continuous carbon-fiber thermoset composite core.

Utilities are inherently conservative and test every new conductor technology and even every new size to ensure that no unintended consequences occur from a product change. They are tasked with reliability and want to make sure that new iterations perform as promised and that there are no unforeseen consequences. They are also deliberate and intentional in adopting advanced material cores because a comprehensive set of industry standards have yet to be adopted for performance of conductors and the tools, methods, and accessories used with them.

International and U.S. Adoption

Recognizing the ability of advanced conductors to deliver increased transmission capacity in a short timeframe, several countries are pursuing extensive reconductoring projects and, in some cases, using advanced conductors in new lines. According to the Berkeley/GridLab analysis, over 90,000 miles of advanced conductors were deployed worldwide between 2003 to 2023. The Idaho National Laboratories found that the primary use case for advanced conductors in restructuring was when the load profile of a line had increased in ways that were not anticipated by the original design, when structures were in good condition, and right of way constricted.

In densely populated regions like Europe, composite-core conductors are used almost exclusively for short reconductoring projects. For instance, in the United Kingdom, the Scottish and Southern Electricity Networks reconductored a 27-mile line in 2017 with ACCC, doubling its capacity without expensive tower modification.[30] ACMs are also being used to adapt to renewable sources. To handle increased power transfer caused by wind generation during off-peak periods, the German utility Westnetz replaced an ACSR line with ACCC in 2011. Although the price of ACCC was higher than other alternatives (ACSS or double-circuit ACSR), they would have required tower modifications equivalent to the extra ACCC cost and taken much more time.[31]

Advanced conductor materials have been widely adopted in the United States. As of 2023, 70% of the 40 major U.S. utilities surveyed by Idaho National Laboratories have deployed advanced conductors on at least a limited basis.[32] Of those, American Electric Power (AEP) has been the largest domestic user of ACCC, having installed it on 26 lines for a total of 447 miles. Faced with rapid population growth in southern Texas and seasonal demands that exceeded projections, AEP used ACCC in 2015 to reconductor a 240-mile existing line rather than run the risk of permitting delays and difficult right-of-way acquisition. Although the same diameter as the original conductor, the ACCC was lighter, generated less heat, and produced less sag. Because the ACCC contained 28% more aluminum, it was able to successfully double the line's capacity and, using techniques developed by Quanta Services, did so without taking it out of service. This is the longest ACCC deployment in the United States. [33] [34]

---

[30] Pat Howe and Dave Bryant, "SSEN Transmission Extends the Asset Life and Capacity of Existing Towers," *T&D World*, November 16, 2021, https://www.tdworld.com/overhead-transmission/article/21181394/ssen-transmission-extends-the-asset-life-and-capacity-of-existing-towers.

[31] Admin, Motionmill, "Westnetz Germany finds a fast, efficient and cost-effective solution – ACCC conductor," Lamifil, September 13, 2018, https://lamifil.be/2017/02/accc/.

[32] Idaho National Laboratories categorizes ACSS as an advanced conductor.

[33] "Energized Rebuild," *T&D World*, August 25, 2016, https://www.tdworld.com/overhead-transmission/article/20966811/energized-rebuild.

[34] ""Record Energized Reconductor Project Brings Reliable Power to South Texas," *EnergyBiz*, season-01 2016, https://www.quantaenergized.com/wp-content/uploads/2015/05/EEI-Energy-Biz_pages.pdf.

Dominion Energy says that it has installed 800 miles of high temperature low sag conductors in its system, reporting that they have 50 percent more capacity than the lines they replaced.[35] In Northern Virginia, it completed the Loudoun-Brambleton line in close proximity to the Dulles airport in 2009. The ACCR line increased capacity by 90%. In 2023, it reconductored 6.7 miles between the Beaumeade and Belmont substations with ACSS to improve service to Loudoun County's Data Center Alley.

Accelerating ACM Adoption

The Berkeley/GridLab study found that there was a strong case to be made for deploying advanced conductor materials for reconductoring. Transmission owners can up to double the capacity of existing lines by swapping out conventional ACSR cables with a variety of advanced conductor technologies. They tend to be about two to three times the cost of conventional conductors, but when compared to the cost of a new transmission line to add a similar capacity increase, reconductoring with advanced conductors can be 50% to 75% cheaper.

However, there are other issues that utilities must consider in deciding to reconductor with advanced conductor materials. Their paramount concern is the continuous supply of power. This means being able to repair high temperature low sag conductors during all load periods while they are in service. The utility industry has developed time-tested methods to maintain and repair traditional ASCR lines to do this. These include live-line tools such as hot sticks or barehand methods that isolate workers from the ground. High temperature low sag conductors operate at temperatures up to 250°C, or 482°F. When conductors operate at such high temperatures, workers cannot employ traditional barehand repair methods, and there are situations where hot sticks cannot be used. As a result, some companies—including Entergy, SCE, Nevada Energy, PG&E, and PacifiCorp—have de-energized lines while reconductoring.

In some case, the power can be moved to other lines, but as the demand for power increases, these alternate routes may not have the necessary additional capacity, which means that customer outages may be necessary.

However, as AEP's Lower Rio Grande Valley project demonstrates, specialized energized barehand work methods can be developed and robotic arms deployed reliably. Robotic arms are used to safely move and securely hold energized power lines in place while conductors, insulators, and structures are maintained, replaced, or rebuilt.[36] Dominion Energy has recently started to leverage energized reconductoring construction methods so that lines can be uprated without the need to take an outage.

---

[35] Ethan Howland, "21 states, DOE launch initiative to spur grid-enhancing technologies, advanced conductors," *Utility Dive*, May 29, 2024, https://www.utilitydive.com/news/states-doe-modern-grid-deployment-initiative-gets/717338/.

[36] "Record Energized Reconductor Project Brings Reliable Power to South Texas," *EnergyBiz*, season-01 2016, https://www.quantaenergized.com/wp-content/uploads/2015/05/EEI-Energy-Biz_pages.pdf.

In order to ensure transmission lines are built within safety guidelines, utilities must also consider the stronger electric and magnetic fields that are generated by higher-capacity conductors. To ensure they do not exceed safety standards, they may have to raise transmission towers or widen the right of way, creating additional cost.

It is important to emphasize that the line conductor is only one of many pieces of primary equipment in the current-carrying path used to determine the rating of a transmission line. in many cases, line terminal equipment (e.g., switches, breakers, wave traps, leads/risers, etc.) at the substation can impose a limit on a transmission line. When considering the benefits of advanced conductors, utilities must also carefully consider the limits posed by terminal equipment.

High Voltage Direct Current (HVDC)

At a Glance: Issues Raised by Del. Reid

- **Can more easily be placed underground because the current does not attenuate into the ground**. Because HVDC systems do not produce a capacitive charge, they do not lose power when placed underground.
- **Is better at accepting power from renewable energy sources**. Because HVDC currents can be precisely controlled, HVDC makes it easier to regulate their flow from intermittent energy sources and deliver them to load centers where they are needed.
- **Can deliver more power from source to destination without power loss along the route**. The U.S. Department of Energy states that HVDC losses can be up to 30% to 50% lower than comparable HVAC systems.
- **Can be scaled to much higher voltages than existing 500kV AC lines.** China has completed a several ultra-high-voltage direct current 1,000 kV and 1,100 kV lines to bring energy from remote generation facilities to population centers. There are no plans to introduce them in the United States. While more efficient than HVDC lines, they face currently insurmountable technological, financial, and environmental hurdles.

In the early years of our country's electric grid, AC became the standard system for transmitting electricity because DC power systems were expensive and technically complex. Since then, advances in power electronics have made High Voltage Direct Current (HVDC) transmission more economical than before. On a typical HVDC link, power is sent to a converter station, where the current is converted from AC to DC. Power is then transmitted over HVDC cables to a second converter station, which converts the power back to AC to be sent to end users.

HVDC technology has been utilized for decades. It is inherently more efficient than HVAC for moving power at low losses and is not subject to its voltage and stability limitations. However, the high costs related to AC-to-DC converter stations have limited its applications, giving it a breakeven distance of approximately 375 to 500 miles for new lines and as short as 200 miles for upgrading existing HVAC corridors.[37] For underground cables, the breakeven distance is estimated to be between 30 and 50 miles. For underwater cables, it is between 15 and 40 miles.[38]

The first HVDC system in the United States—the 500-kV Pacific DC Intertie completed in 1970—allowed the delivery of 3,100 MW of low-cost hydropower—a renewable energy source—from the Pacific Northwest to load centers in Southern California. Since then, several additional HVDC lines have been added for similar purposes, for instance, to bring 2,000 MW of hydroelectric power on lines capable of operating at 450 kV from northern Quebec to New England.

If properly configured, direct current transmission could also play a crucial role in better correlating energy supply with demand for intermittent renewable sources like wind and solar. This is because the flow of electricity through HVDC cables can be easily controlled at the converter stations.[39] The newest converters also provide grid support functionalities, such as reactive power control, voltage control, and black start capabilities, essential for stabilizing power grids with intermittent renewables.

HVDC is also deployed extensively for underwater cable systems. In the United States, these tend to be short. They include Trans Bay Cable in San Francisco (±200 kV, 400 MW, 53 miles), Cross Sound Cable (± 150 kV, 330 MW, 25 miles), Neptune Cable (550 kV, 660 MW, 65 miles), and Hudson Transmission Partners (345 kV, 660 MW, 3 miles).[40] The North Sea Link (±515 kV, 1400 KW), completed in 2021 between the United Kingdom and Norway, at 450 miles, is the longest in the world.

Although not germane to the Commonwealth, HVDC is also used for power transmission between large unsynchronized AC power grids, that is, grids that are running at different frequencies. This helps improve system stability by preventing cascading failures from propagating from one grid to the other. There are more than 15 back-to-back HVDC facilities or AC-AC interties between the grid networks in North America, including the Eastern Interconnect, Western Interconnect, Electricity Reliability Council of Texas, and Comisión Federal de Electricidad (CFE) in Mexico

---

[37] Liza, M. Reed, Granger Morgan, Parth Vaishnav, and Daniel Erian Armanios, "Converting existing transmission corridors to HVDC is an overlooked option for increasing transmission capacity," *Proceedings of the National Academy of Sciences*116, no. 28 (June 20, 2019): 13879–84, https://doi.org/10.1073/pnas.1905656116.
[38] "ABB review special report." *ABB Review Special Report*, 2014, https://library.e.abb.com/public/aff841e25d8986b5c1257d380045703f/140818%20ABB%20SR%2060%20years%20of%20HVDC_72dpi.pdf.
[39] News | NREL, "On the Road to Increased Transmission: High-Voltage Direct Current," n.d. https://www.nrel.gov/news/program/2024/on-the-road-to-increased-transmission-high-voltage-direct-current.html.
[40] "Assessing HVDC Transmission for Impacts of Non-Dispatchable Generation," United States: U.S. Department of Energy, June 2018, https://www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf.

Over 300 GW of HVDC transmission capacity has been installed worldwide, with another 150 GW planned to be installed over the next decade. The majority of the HVDC systems in operation today are overhead based, but the installed capacity of underground systems is rapidly growing.[41]

The Characteristics of HVDC Systems

Because the voltage and current do not alternate, HVDC transmission is inherently more efficient than HVAC and can transmit more power over longer distance with fewer materials.[42]

HVDC takes advantage of the full capacity of the conductor: The changing magnetic fields induced by alternating current pushes the current to the outer layer, or skin, of the electrical conductor, reducing the effective available conductor, increasing the conductor's resistance, and limiting its capacity to carry high currents.

The skin effect does not exist in DC systems. Consequently, DC systems optimize the use of conductor material and increase the efficiency of any given conductor design. Alternatively, they can use smaller and lighter conductors to offer the same power transfer as larger AC lines.

The optimal use of conductor material means that the cost per mile of DC transmission lines is lower than that of AC lines. For overhead lines, the use of fewer and lighter conductors is also associated with cost savings from narrower rights of way, smaller transmission towers, and fewer insulators because they do not need to carry as much weight.

HVDC does not produce reactive power: Reactive power, produced by line capacitance and inductance, is the power that flows back and forth between the source (generation) and the load (homes, data centers, etc.) in an AC line. It can be described as a form of resistance that limits the capacity and distance of power transfer. Reactive power does not produce useful work and is particularly pronounced in insulated underground and underwater AC cables. DC transmission lines produce no reactive power.

Because HVDC does not generate reactive power, the technically feasible transmission distance of HVDC cables is practically unlimited. HVDC cables can run underground and underwater as well as through the air with significantly less energy loss compared to comparable AC cables.[43] *Consequently, they are ideal for transmitting electricity from offshore wind farms.*

---

[41] Johannes P. Pfeifenberger, Linquan Bai, Andrew Levitt, Cornelis A. Plet, and Chandra M. Sonnathi, "The Operational and Market Benefits of HVDC to System Operators," 2023, https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf.
[42] Pfeifenberger.
[43] "Benefits of HVDC Transmission Systems | Cence Power," n.d. https://www.cencepower.com/blog-posts/hvdc-transmission-systems#:~:text=Additionally%2C%20because%20HVDC%20has%20lower,as%20wind%2C%20hydro%20and%20solar.

HVDC does not induce currents in nearby objects: Because of its signals are nonoscillating, HVDC does not magnetically induce currents in nearby metal objects. In particular, it does not induce currents in a conductor's armoring that can limit its power transfer. However, these magnetic fields may have effects on navigational systems used by airports.

Taken all together, the consequence of these characteristics is that, according to the U.S. Department of Energy, HVDC losses can be up to 30% to 50% lower than comparable HVAC systems, further reducing long-term costs.[44]

The potential of HVDC is clear. In the United States, some utilities, like Dominion Energy, have constructed a number of HVAC transmission lines so that they could eventually accommodate HVDC transmission. Researchers are now focusing on advanced HVDC systems. Currently, HVDC systems are point-to-point systems. Developers are working to create mesh HVDC networks, allowing multiple nodes to connect to each other enhancing redundancy and flexibility, but this technology is not available today for deployment.

Some of the characteristics that produce HVDC's superior performance, however, also make it more difficult to control safely. However, developments in power electronics, particularly voltage sourced converters and switches, have addressed many of these issues as well as improving integration performance with the AC grid and enabling the creation of multiterminal, interconnected HVDC transmission grids. Companies are working to design technology to detect, isolate, and mitigate faults on mesh DC systems. In addition, there have been recent developments in conventional transformer technology. A Central Virginia company manufactures substation-level devices with a claimed efficiency of 99.7%, which is substantially greater than achieved by power electronics.

Ultra-High-Voltage Direct Current

Ultra-high-voltage direct current (UHVDC) lines (rated at 800 kV and above) transmit power even more efficiently than HVDC lines. They are used in China and, to a much lesser extent in Brazil and India, to transmit power over extremely long distances. For instance, in January 2019, China energized the Changji-Guquan UHVDC link, which spans 1,900 miles. It is rated at 1,100-kV and provides 12 GW of transmission capacity. The completion of this project set world records for HVDC lines in terms of voltage, transmission capacity, and line length.[45] I

China has subsequently completed several other UHVDC projects, ranging from 680 to 1,400 miles It accounts for 80% of the existing UHVDC links, with India and Brazil supplying the rest. All of these transmissions lines were created to move power from remote locations where it is generated to populations centers where it is needed.

[44] Energy.gov. "Connecting the Country with HVDC," n.d. https://www.energy.gov/oe/articles/connecting-country-hvdc.

[45] "What does it take to bring power to millions? – Changji-Guquan 1,100kV UHVDC," n.d. https://www.hitachienergy.com/us/en/news-and-events/customer-success-stories/changji-guquan-uhvdc-link#:~:text=The%20link%20is%20capable%20of,kV%20UHVDC%20links%20in%20operation.

Adaption in other countries will require the development of specialized converter stations and enhanced insulation, a well-trained workforce, and an immense investment. If these obstacles were overcome, they might be used in the United States for such tasks as transmitting solar power generated in the afternoon in California to cities on the East Coast in the evening or to distribute wind power in the Midwest to more populated areas. However, they would not be used at the end of the transmission network to deliver power to specific facilities in an area like Loudon County.

Grid-Enhancing Technologies

Dynamic Line Ratings

Grid-Enhancing Technologies (GETs) are hardware and/or software technologies that can increase the capacity, efficiency, reliability, and safety of existing transmission lines.[46] GETs can help reduce congestion costs, improve integration of renewables, and increase capacity. Virginia's governor signed HB 862, which requires the state's electric utilities to consider GETs in their integrated resource plan.[47] It is important to note that GETs provide useful tools to operate the grid more efficiently and reliably, but they do not replace careful planning for grid expansion.

One example of a GET is dynamic line ratings (DLR). A transmission line's loading limit is typically static—often with some seasonal variation—determined by the heat-tolerance of the equipment and very conservative assumptions about the ambient conditions, such as air temperature, wind speed and direction, solar insolation, etc. A DLR system monitors line conditions to determine the safe carrying capacity of the line in real time, with a variety of commercially available sensor-based technological solutions. A DLR system enables higher power flows, especially in cooler or windier conditions, while limiting power flows in extreme heat or other weather conditions to ensure safe and reliable operation.[48]

While it might be straightforward to place a DLR sensor on a line tower, there is nothing easy about integrating dynamic line ratings into a grid operator's EMS system, incorporating the ever-changing rating into operating procedures, or developing an industry-wide standard on which rating to in planning studies. The application of DLRs is still new, and the industry is beginning to learn how to approach them.

---

[46] "What are GETs?," WATT, June 26, 2024, https://watt-transmission.org/what-are-grid-enhancing-technologies/#:~:text=GETs%20are%20hardware%20and%2For,have%20parallels%20to%20traffic%20control.
[47] Ethan Howland, "21 states, DOE launch initiative to spur grid-enhancing technologies, advanced conductors," *Utility Dive*, May 29, 2024, https://www.utilitydive.com/news/states-doe-modern-grid-deployment-initiative-gets/717338/.
[48] Chojkiewicz et al.

As part of a $33.7 million grant received in 2023 from the U.S. Department of Energy $10.5 billion Grid Resilience and Innovation Partnerships program, Dominion Energy is deploying the world's largest DLR project, placing the technology on more than two dozen powerlines. This deployment will allow it to increase the electrical capacity supplied in certain areas without constructing additional transmission lines.

Again, it is important emphasize that the deployment of DLR technology does not replace the need to build transmission lines or careful transmission system planning to address extreme heat or other weather conditions.

Gas-Insulated Lines

Purchasing right of way in urban areas to add overhead high-voltage transmission lines is both time consuming and expensive—if it is even available. An alternative now being deployed in Europe is gas-insulated lines (GIL). Because electric fields are completely shielded and magnetic fields substantially reduced, they need less right of way and can be installed along roadways. They are available voltages compatible with those used in Virginia, but the cost to install a GIL line is higher than a traditional line, requiring government support to install and government approval for use in transportation corridors.

References

"2024 Global Data Center Market Comparison," n.d. https://cushwake.cld.bz/2024-Global-Data-Center-Market-Comparison/2/.

"21 states, DOE launch initiative to spur grid-enhancing technologies, advanced conductors." *Utility Dive*, May 29, 2024. https://www.utilitydive.com/news/states-doe-modern-grid-deployment-initiative-gets/717338/.

"ABB review special report." *ABB Review Special Report*, 2014. https://library.e.abb.com/public/aff841e25d8986b5c1257d380045703f/140818%20ABB%20SR%2060%20years%20of%20HVDC_72dpi.pdf.

Admin, Motionmill. "Westnetz Germany finds a fast, efficient and cost-effective solution – ACCC conductor." Lamifil, September 13, 2018. https://lamifil.be/2017/02/accc/.

Admin. "2035 Report | Reconductoring with advanced conductors can accelerate the rapid transmission expansion required...," June 21, 2024. https://www.2035report.com/reconductoring/.

"Advanced Conductor Scan Report, Revision 1." United States of America: Idaho National Laboratory, April 2024. Accessed August 6, 2024. https://inl.gov/content/uploads/2024/02/23-50856_R8_-AdvConductorszScan-Report.pdf.

"Advanced Transmission Technologies," 2020. https://www.energy.gov/sites/prod/files/2021/02/f82/Advanced%20Transmission%20Technologies%20Report%20-%20final%20as%20of%2012.3%20-%20FOR%20PUBLIC.pdf.

ANS / Nuclear Newswire. "2024: The State of Advanced Reactors," n.d. https://www.ans.org/news/article-5634/2024-the-state-of-advanced-reactors/.

"Assessing HVDC Transmission for Impacts of Non-Dispatchable Generation." United States: U.S. Department of Energy, June 2018. Accessed August 8, 2024. https://www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf.

Augenstein, Neal. "Why is Northern Va. the world's data center capital?" *WTOP News*, October 25, 2022. https://wtop.com/virginia/2022/10/why-is-northern-va-becoming-the-worlds-data-center-capital/.

"Benefits of HVDC Transmission Systems | Cence Power," n.d. https://www.cencepower.com/blog-posts/hvdc-transmission-systems#:~:text=Additionally%2C%20because%20HVDC%20has%20lower,as%20wind%2C%20hydro%20and%20solar.

Blue, Robert M. "Powering Your Every Day 2023 Annual Report," March 7, 2024. https://s2.q4cdn.com/510812146/files/doc_downloads/2024/2024/03/21/Dominion-Energy-2023-Annual-Report-and-Annual-Report-on-Form-10-K-1.pdf.

"Chapter 3 | Portfolios." *Carolinas Resource Plan*, n.d. https://www.duke-energy.com/-/media/pdfs/our-company/carolinas-resource-plan/chapter-3-portfolios.pdf?rev=4351b5246a2f4172a93b7a019df3fcf7.

Chojkiewicz, Emilia, Umed Paliwal, Nikit Abhyankar, Casey Baker, Ric O'Connell, and Duncan Callaway. "RECONDUCTORING WITH ADVANCED CONDUCTORS CAN ACCELERATE THE RAPID TRANSMISSION EXPANSION REQUIRED FOR A CLEAN GRID," 2021.

https://www.2035report.com/wp-content/uploads/2024/04/GridLab_2035-Reconductoring-Technical-Report.pdf.

Dominion Energy MediaRoom. "Dominion Energy takes important step to determine feasibility of Small Modular Reactor (SMR) technology to support customers' needs," July 10, 2024. https://news.dominionenergy.com/2024-07-10-Dominion-Energy-takes-important-step-to-determine-feasibility-of-Small-Modular-Reactor-SMR-technology-to-support-customers-needs.

Dominion Energy MediaRoom. "Dominion Meets Record Winter Peak Demand for Electricity from Customers," n.d. https://news.dominionenergy.com/news?item=70848#:~:text=One%20megawatt%20supplies%20enough%20electricity,to%20all%20of%20those%20customers.

Energy.gov. "Connecting the Country with HVDC," n.d. https://www.energy.gov/oe/articles/connecting-country-hvdc.

Energy.gov. "Connecting the Country with HVDC," n.d. https://www.energy.gov/oe/articles/connecting-country-hvdc.

Energy.gov. "NRC Certifies First U.S. Small Modular Reactor Design," n.d. https://www.energy.gov/ne/articles/nrc-certifies-first-us-small-modular-reactor-design.

Faleski, Stephen. "Surry approves nuclear-powered data center campus that promises more than 1,300 jobs - Smithfield Times." Smithfield Times, February 12, 2024. https://www.smithfieldtimes.com/2024/02/12/surry-approves-nuclear-powered-data-center-campus-that-promises-more-than-1300-jobs/.

"Funds awarded to assist Xe-100 deployment in the UK: New Nuclear - World Nuclear News," n.d. https://www.world-nuclear-news.org/Articles/Funds-awarded-to-assist-Xe-100-deployment-in-the-U.

Global, Ctc. "SSE won capital project of the Year Award for ACCC® Reconductor Project." CTC Global, April 23, 2024. https://ctcglobal.com/sse-wins-capital-project-of-the-year-award-for-accc-reconductor-project/.

"High Temperature Low Sag Conductors (HTLS) - ENTSO-E," n.d. https://www.entsoe.eu/Technopedia/techsheets/high-temperature-low-sag-conductors-htls#:~:text=High%20Temperature%20Low%20Sag%20Conductors%20(HTLS)%20can%20withstand%20operating%20temperatures,power%20compared%20to%20conventional%20conductors.

Howe, Pat, and Dave Bryant. "SSEN Transmission Extends the Asset Life and Capacity of Existing Towers." *T&D World*, November 16, 2021. https://www.tdworld.com/overhead-transmission/article/21181394/ssen-transmission-extends-the-asset-life-and-capacity-of-existing-towers.

Howland, Ethan. "21 states, DOE launch initiative to spur grid-enhancing technologies, advanced conductors." *Utility Dive*, May 29, 2024. https://www.utilitydive.com/news/states-doe-modern-grid-deployment-initiative-gets/717338/.

IAEA. "What are Small Modular Reactors (SMRs)?," n.d. https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs#:~:text=Small%20modular%20reactors%20(SMRs)%20are,of%20traditional%20nuclear%20power%20reactors.

Laying the Foundation for New and Advanced Nuclear Reactors in the United States. *National Academies Press eBooks*, 2023. https://doi.org/10.17226/26630.

Minnix, John. “115 Data Center Stats You Should Know In 2024.” Brightlio - Technology Illuminated, April 22, 2024. https://brightlio.com/data-center-stats/.
News | NREL. “On the Road to Increased Transmission: High-Voltage Direct Current,” n.d. https://www.nrel.gov/news/program/2024/on-the-road-to-increased-transmission-high-voltage-direct-current.html.
O’Boyle, Mike, Casey Baker, and Michelle Solomon. “SUPPORTING ADVANCED CONDUCTOR DEPLOYMENT: BARRIERS AND POLICY SOLUTIONS,” April 9, 2024. https://www.2035report.com/wp-content/uploads/2024/04/Supporting-Advanced-Conductor-Deployment-Barriers-and-Policy-Solutions.pdf.
Pearl, Larry. “NuScale, UAMPS terminate small modular reactor project in Idaho.” *Utility Dive*, November 9, 2023. https://www.utilitydive.com/news/nuscale-uamps-terminate-small-modular-nuclear-reactor-smr-project-idaho/699281/.
Pfeifenberger, Johannes P., Linquan Bai, Andrew Levitt, Cornelis A. Plet, and Chandra M. Sonnathi. “THE OPERATIONAL AND MARKET BENEFITS OF HVDC TO SYSTEM OPERATORS.” *THE OPERATIONAL AND MARKET BENEFITS OF HVDC TO SYSTEM OPERATORS*, 2023. https://www.brattle.com/wp-content/uploads/2023/09/The-Operational-and-Market-Benefits-of-HVDC-to-System-Operators-Full-Report.pdf.
“Plant Vogtle Unit 4 begins commercial operation - U.S. Energy Information Administration (EIA),” n.d. https://www.eia.gov/todayinenergy/detail.php?id=61963#:~:text=The%20two%20new%20reactors%20bring,plant%20in%20the%20United%20States.
“Q1 2024 Earnings Call,” May 2, 2024. https://s2.q4cdn.com/510812146/files/doc_financials/2024/q1/2024-05-02-DE-IR-1Q-2024-earnings-call-slides-vTC.pdf.
“RECONDUCTORING WITH ADVANCED CONDUCTORS CAN ACCELERATE THE RAPID TRANSMISSION EXPANSION REQUIRED FOR A CLEAN GRID,” 2021. https://www.2035report.com/wp-content/uploads/2024/04/GridLab_2035-Reconductoring-Technical-Report.pdf.
“Record Energized Reconductor Project Brings Reliable Power to South Texas.” *EnergyBiz*, season-01 2016. https://www.quantaenergized.com/wp-content/uploads/2015/05/EEI-Energy-Biz_pages.pdf.
Reed, Liza, M. Granger Morgan, Parth Vaishnav, and Daniel Erian Armanios. “Converting existing transmission corridors to HVDC is an overlooked option for increasing transmission capacity.” *Proceedings of the National Academy of Sciences* 116, no. 28 (June 20, 2019): 13879–84. https://doi.org/10.1073/pnas.1905656116.
T&D World. “Energized Rebuild,” August 25, 2016. https://www.tdworld.com/overhead-transmission/article/20966811/energized-rebuild.
Utility Dive. “NuScale CEO touts data center deal, heavy industry SMR interest amid "80M loss for 2023,” March 15, 2024. https://www.utilitydive.com/news/nuscale-small-modular-reactor-smr-data-center-nuclear/710442/.
Utility Dive. “TerraPower begins construction at 345-MW advanced reactor site in Wyoming,” June 12, 2024. https://www.utilitydive.com/news/terrapower-smr-advanced-nuclear-reactor-bill-gates/718722/.
“Virginia Data Centers,” n.d. https://www.datacentermap.com/usa/virginia/#.

WATT. "What are GETs?," June 26, 2024. https://watt-transmission.org/what-are-grid-enhancing-technologies/#:~:text=GETs%20are%20hardware%20and%2For,have%20parallels%20to%20traffic%20control.
"What does it take to bring power to millions? – Changji-Guquan 1,100kV UHVDC," n.d. https://www.hitachienergy.com/us/en/news-and-events/customer-success-stories/changji-guquan-uhvdc-link#:~:text=The%20link%20is%20capable%20of,kV%20UHVDC%20links%20in%20operation.
X-energy. "Dow | X-energy — X-energy," n.d. https://x-energy.com/seadrift.