COVER PAGE

Project Title: Enabling the Clean Energy Transition by Enhancing Grid Stability Using SmartValve Technology

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Project Locations: Illinois and Texas

Statements Regarding Confidentiality: No statements of confidentiality

Figure 1. SmartValve installations at Transgrid substation in Australia.

PROJECT AND TECHNOLOGY DESCRIPTION

1. PROJECT OVERVIEW

1.1 The Need and General Solution

The clean energy transition is being severely impacted by stability limits on existing transmission grids around the country. These limitations impact the transition to clean energy in two ways: by slowing down or preventing the addition of new renewable generators to the grid, and by limiting the output of existing renewable generating facilities.

The standard means to deal with stability issues is to build new transmission lines with their accompanying high cost, long lead time, and impacts to the public. An alternative, lower cost, and faster approach with miminal public impacts is to deploy technologies, such as the SmartValve solutions contained in this proposal, on the *existing* transmission system to alleviate stability issues.

There is growing recognition of the potential this type of Grid Enhancing Technology (GET) could have in the United States. A 2022 Department of Energy report on GETs found there is "ample opportunity to support existing grid infrastructure and alleviate existing transmission constraints, as well as future constraints from expected shifts in power supply and demand."[1] A 2021 WATT Coalition *Unlocking the Queue with Grid Enhancing Technologies* report showed that on a national scale, GETs could deliver "carbon emissions cuts equal to taking 20 million cars off the road (90 million tons per year); $5 billion in yearly energy cost savings; 330,000 local construction jobs, 20,000 high-paying operations jobs, and double the amount of renewables that can be integrated prior to building large scale transmission lines."[2]

This project centers on two use cases that will deploy SmartValves on the existing transmission grid in two distinct regions, increasing the electricity transfer capability of the grid to allow clean energy to reach the loads it was intended to serve, and decreasing the time and cost associated with interconnecting new renewable facilities.

1.2 Project Focus and Use Cases

This project will address stability-related grid transfer capacity challenges using SmartValves, a GET in the form of an advanced Static Synchronous Series Compensator (SSSC). The SmartValve technology from US based Smart Wires Inc., is a proven, revolutionary modular technology that has been successfully deployed to improve the capability and stability of existing transmission systems globally, but has had limited adoption in certain areas of the US power grid.

We propose to install SmartValves in two distinct deployments in different regions of the country with diffent system operators, PJM and ERCOT. These deployments will demonstrate SmartValves as a cost-effective means of increasing utilization of existing transmission assets. This increased utilization will enable more timely integration of renewable facilities to the grid, help to ensure that the production of clean electricity from existing renewable assets is able to get to power consumers, and avoid community impacts associated with new transmission lines. By acting as demonstration anchor projects in these regions, the deployments will also reduce cost and time associated with future GET installations by increasing regional familiarity and experience with these technologies.

A description of the two use cases follows. In the case of PJM, the technology will be deployed to resolve stability issues in northern Illinois, supporting the integration of new generation resources onto the grid. In the case of ERCOT, the technology will be deployed in the Lower Rio Grande Valley (LRGV) to help reduce existing Generic Transmission Constraints (GTCs) which are limiting the transfer capacity of clean energy out of and into the region.

These two use cases are widely representative of the increasing number of network limitations caused by instabilities that impact renewable energy generators and consumers across the U.S.

By resolving stability issues the project is expected to **increase transmission capacity by approximately 300 MW** across both regions (105MW in northern Illinois and 186MW in the LRGV) and increase the resilliency of the existing grid. Estimates supporting this increase are presented in Section 2.2.4.

1.2.1 <u>Northern Illinois</u>

Lee County in northern Illinois has a major new wind facility ready to connect to the ComEd (Commonwealth Edison, an Exelon company) 138 kV transmission system (Figure 2): the 105 MW Shady Oaks 2 wind facility owned by Algonquin. As identified in the revised PJM System Impact Study, no further renewable generation can be added in this area due to stability limitations of the existing grid, without significant stability upgrades. The initially proposed solution to resolve these lately identified stability issues was to construct a new transmission line at an estimated cost of **$180M** over a timeframe of 3-5 years.

Deploying SmartValve technology on one of the existing transmission lines would enhance grid stability, enable the reliable interconnection of this 105MW wind facility, enhance system resilience, and cost far less (about **$29M** total).

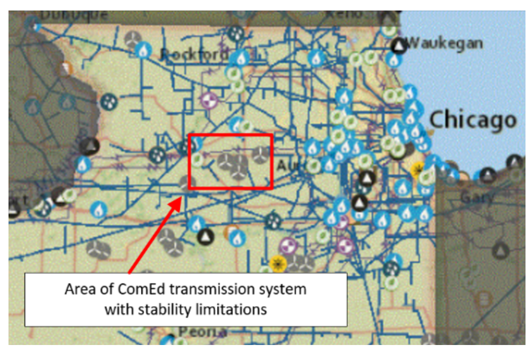

Figure 2. IL wind facility and transmission area.

Shady Oaks 2 is ready to interconnect to the grid and once operational, the project will reduce emissions on the Illinois system by approximately 106,000 tons of CO2 per year, or the equivalent of removing 21,000 conventional cars from the roads. Shady Oaks 2 will inject capital into the community by supporting local farmers who will earn additional revenues helping to stabilize their farming incomes once the facility is able to interconnect. It is anticipated to contribute in excess of $1.1 million per year in property tax revenue as well as fund an already developed community benefits agreement with the village of Paw Paw, Illinois.

As well as providing the immediate benefit of opening up 105MW of interconnection room on the grid in Illinois, due to the modular nature of the SmartValve technology, this deployment will be scalable in the future, allowing additional projects to interconnect to the system as well without triggering the need to build a new transmission line as a result of stability issues. Currently, at least four additional renewable energy projects are proposed in the area. Studies have shown that at least 100MW of additional interconnection capacity can be opened up by increasing the size of the initial SmartValve deployment in the future. (This 100MW would be in addition to the 300MW of benefits already associated with the project as a whole.)

1.2.2 Lower Rio Grande Valley (LRGV) in South Texas

Once renewable projects have been added to the grid, ensuring they can operate at their maximum output levels is key to realizing the environmental, economic, and community benefits associated with these facilities. ~7 GW of renewable energy projects are operational in South Texas, including three Algonquin wind farms (Figure 3). The Electric Reliability Council of Texas (ERCOT) region has experienced significant growth in renewable generators, increasing the number and complexity of stability limits on the system. An estimated 6% of the renewable generation in south Texas is currently curtailed due to increased implementation of Generic Transmission Constraints (GTCs) by ERCOT. In 2014 ERCOT applied only 4 GTCs; by the end of 2022 about 16 GTCs were in operation. These GTCs manage system stability by limiting total simultaneous operational transfer capacity across multiple transmission lines to a level significantly below their combined physical capabilities. This project addresses limitations imposed by two of these GTCs impacting the LRGV region, the *Valley Export GTC* and *Valley Import GTC*.

The ***Valley Export GTC*** limits the power flowing north, causing LRGV region generator curtailments, and requiring additional coal and gas-fired electricity production to be dispatched closer to the load (particularly in the Houston load center) to serve customers. The net effect is that renewables are turned down while fossil fuel generation is turned up, driving up emissions and costs for consumers in South Texas and eroding the environmental benefits associated with the renewable facilities. Likewise, during periods of low renewable generation in the LRGV, the ***Valley Import GTC*** limits power flowing south to consumers, increases the cost and associated emissions for consumers, and imposes the risk of load curtailments in the LRGV region.

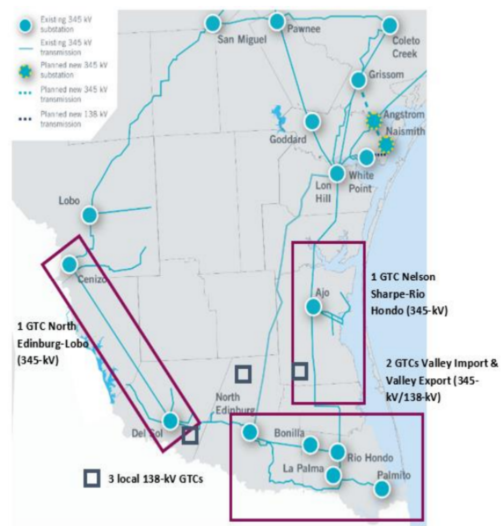

Figure 3. TX Location and relevant substations associated with Valley Import and Export GTCs.

The deployment in South Texas would install SmartValve units on two of the 345kV interface lines associated with these two GTCs, increasing the transfer capacity by an estimated **186MW** and thereby reducing the necessary level of curtailments and costs associated with these constraints. The estimated cost for this deployment is **$55 million,** and resolves an existing issue significantly faster than new transmission lines can be constructed.

The LRGV is a potentially attractive area for new industrial customers to site, particularly in the hydrogen production sector. However, the current costs and curtailments associated with the GTCs make it less attractive for both customers and renewable generators to make further investment in the LRGV area. From a generator perspective, having the GTCs in place has seriously impaired the profitability of the generating assets in this region. Many renewable generators (including Duke and Enbridge) have been forced to write down the value of their existing assets in this region, dis-incentivizing future renewable generating investment in the area if these conditions persist. Resolving the GTCs by reducing curtailments would help to spur new clean industrial and generation investments in the region, as well as increasing payments to: (a) farmers under leases with these facilities, (b) to the general community under community benefit arrangements, and (c) local government through property taxes.

1.3 Applicant and Partner Organizations

Prime applicant ***Algonquin Power Fund (America), Inc. (Algonquin)*** is the non-regulated US renewable generation arm of Algonquin Power & Utilities Corp. (APUC), a diversified international generation, transmission, and distribution utility with over $16 billion of total assets. APUC is a global leader in renewable energy through its portfolio of wind, solar, and hydroelectric generating facilities. Algonquin has a renewable generation portfolio of over 2,700MW in construction and operation in the United States. Algonquin owns projects in the two regions facing the stability challenges address in this proposal, including the Shady Oaks 1&2 projects in Illinois, and the Stella and East and West Raymond facilities in Texas. Algonquin is an experienced developer, constructor, and owner/operation of renewable assets.

Contractor ***Smart Wires, Inc.,*** the technology partner, is headquartered in North Carolina and is a global power technology company advancing the delivery of affordable, clean electricity worldwide. The dedicated manufacturing facility in St. Petersburg, FL, is owned and staffed by JABIL, a global manufacturing company. Smart Wires is an ISO-9001:2015 registered company. SmartValve has been deployed on 39 different circuits across the globe, generating over 3200 device-years of field experience for utilities on 4 continents. Each project has unlocked 170 MW to 1,500 MW of capacity on existing transmission assets. With innovative technology and advanced analytics, Smart Wires' goal is to maximize the grid's capacity using more renewables, at a lower cost, and with less disruption to communities and the environment.

Subawardees ***University of Texas – Rio Grande Valley*** and ***Northern Illinois University***, near the project regions, have strong Electrical and Computer Engineering Programs, large minority student and Pell grant recipient enrollment, and are initiating the *Smart Grid Leaders Initiative*.

Other Partners (See Letters of Commitment and Support)

American Electric Power (AEP) Texas is an investor-owned utility, committed to leveraging innovative approaches and technologies to keep customer bills low across their 11-state footprint. As a transmission service provider and asset owner in the LRGV where the South Texas program will be deployed, AEP is intimately familiar with the GTCs. AEP is interested in a technology solution to resolve GTCs in this region. AEP provided ERCOT dynamic models to support the development of the SmartValve solution and has been working with the project team to evaluate the deployment.

***ComEd (Commonwealth Edison* an Exelon company)** is an investor-owned utility and the transmission facility owner in northern Illinois where the SmartValve solution is proposed within the PJM footprint. This solution has been discussed extensively with ComEd and detailed "Facilities Study" level work is proceeding to refine and proceed with detailed design of the installation. ComEd is supportive of grid enhancing technologies and interested in providing a low cost, reliable network upgrade for its generation interconnection customers.

Other Generators. Renewable generators with existing and proposed facilities in the LRGV are impacted by the GTCs, which limit their ability to move power to market, and are interested in participating in the project. These include **RWE Renewables, Duke Energy Sustainable Solutions, EDF Renewables, Energy USA Global LLC, Pattern Greencoat, Acciona**, and others.

Other Collaborators. Other collaborators in the technical project include **PJM**, the independent system operator (ISO) that coordinates wholesale electricity movement in 13 states in the east-central US, and **ERCOT**, the ISO that manages the flow of electric power for about 90 percent of the electric load in the state of Texas. Each will need to approve the use of the SmartValve technology in their jurisdictions. PJM has begun detailed evaluation of the SmartValve solution in Illinois, and discussions with ERCOT are proceeding via the ERCOT Regional Planning Group.

1.4 History Leading to this Project and Readiness

History. A quarter-century ago it was recognized that power electronics would revolutionize the grid. A team of scientists collaborated to introduce Flexible Alternating Current Transmission Systems (FACTS) – a breakthrough for variable power flow control on electricity networks. During the Northeast Blackout of 2003, with 55 million people across North America in the dark, a visionary team at Georgia Tech University developed these ideas further by establishing a smart power flow control concept to allow grid operators to monitor and adjust power flows across their networks in real time. This new technology marked a critical step forward in grid efficiency – and served as the catalyst for a new partnership among some of the US's largest and most-respected utilities. Together the stakeholders launched Smart Wires.

In 2012, Smart Wires and partners received $4M in ARPA-E (Advanced Research Projects Agency – Energy) funding to further develop this technology. A decade later, Smart Wires has engaged in deep strategic partnerships with some of the world's most respected utilities to develop and deploy solutions responding to some of the power industry's most urgent needs: integrating more renewables; increasing grid capacity, flexibility and stability; reducing costs and environmental and community impacts; and preparing for an unpredictable future.

Readiness. SmartValve is a commercially-viable technology at TRL 9 ready to be deployed, with installations across four continents and years of installed experience at leading utilities in Australia (Figure 1), the UK (Figure 4), Colombia, and Canada. The deployments in this proposal build on previous SmartValve experiences. The stability issues facing ERCOT occur in other parts of the world, especially wherever significant renewable generators are connected over relatively long distance to major load centers. For example, the dispersed Australian electricity network relies on renewable energy for 32.5% of its power supply, compared to 12.5% for the US.[3,4] Australia, with 78% of the size of the US and a population less than 10%, generates renewable power that typically travels far to serve the load. For this reason, Australian utilities started dealing with renewable generator-induced network stability issues many years before Texas.

Figure 4. SmartValve installations at National Grid Electric Transmission Substation in England.

The SmartValve deployment in Illinois will address stability issues similar to those experienced by Central Hudson Gas & Electric in New York state. Due to limitations on the grid's transfer capacity, Central Hudson first explored a series capacitor solutions, but this approach was too expensive, required substantial substation space, and would have created serious issues like sub-synchronous resonance (SSR). Seeking alternative solutions, Central Hudson recently contracted for a Smart Valve deployment to be installed in Summer 2023. The installation will decrease the impedance of the Leeds-Hurley 345 kV line, thereby allowing the connection of 185 MW of newly-connected renewable power down the line and avoiding the associated operational risks of traditional series capacitors. Similar stability issues facing Illinois generators have been identified by PJM.

The project benefits from already having kicked off solution development work and transmission owner education in the proposed regions. As part of the Shady Oaks 2 project development, Algonquin and Smart Wires have conducted extensive technical studies of the northern Illinois region, which currently sit with PJM and ComEd for detailed "Facilities Study" level final review, approval, and planning. In Texas, AEP is intimately familiar with the GTCs instituted by ERCOT, as are Algonquin and its fellow generation owners in the region. AEP has expressed interest in seeing a technology solution implemented to resolve the GTCs. AEP provided the project team access to system dynamic models to facilitate the stability mitigation studies performed to develop the SmartValve solution for the region, and is working with the project team to evaluate these results.

This technological maturity lends itself to the proposed projects, which expects installations at both deployment sites by the end of 2025.

1.5 Project Goals

The **short-term goal** of this project is to deploy SmartValve technology in two regions to provide a successful demonstration of cost-effective alternatives that better utilize existing transmission assets, enable timely integration of renewable energy to the grid, and allow existing renewable assets to be fully utilized.

The **long-term goals** are to obtain the most value out of existing transmission assets and speed the clean energy transition by: (1) ***giving confidence in the technology to PJM and regional transmission owners*** so that they will deploy SmartValve and other GET solutions to resolve future generator interconnection (and other stability related) issues—thereby speeding up the interconnection process, reducing the queue backlog, and reducing future generator interconnection costs—ultimately lowering costs to consumers and accelerating the greening of the grid; and (2) ***giving confidence in the technology to ERCOT and regional transmission owners*** to deploy SmartValves and other GET solutions to reduce the use of GTCs to manage system stability issues—thereby reducing costs to consumers, opening up further renewables interconnection capacity, and enabling existing renewable generating assets to be utilized to their full potential.

Following successful deployment, when further implemented on a large scale, community, regional, interregional, and national resilience will be transformed. The national energy transmission transfer capacity will be increased at low cost, and long-term jobs will be generated across the supply chain.

1.6 DOE Impact

DOE funding will play a decisive role in mitigating perceived technology risk, further encouraging deployment of SmartValve technology to resolve the issues identified in these use cases (i.e., stability limitations) rather than resorting to traditional solutions like the construction of additional transmissions lines.

In northern Illinois, DOE funding will lessen the economic impact of the required stability upgrades on the new renewable projects in the area, making these projects more likely to proceed through to interconnection, preventing their cancellation, and enabling delivery of anticipated benefits to the community.

In the LRGV, DOE funding will help improve the economic justification for proceeding with this deployment and reduce GTC levels sooner than the new transmission lines anticipated in the region can be built. Even after new lines are constructed, it will continue to provide benefits by increasing the operational transfer capacity of the existing lines, helping to incent both new renewable generators and loads to locate in this economically disadvantaged area. It will reduce customer costs and related emissions by lowering the amount of coal and gas power production used to serve loads, and provide increased resiliency during extreme weather events. This DOE project will set an example for others on how to build a coalition to take economically justified projects forward to the Regional Planning Group in ERCOT, a route that hasn't been pursued to justify a new transmission related project since 2019.

1.7 Community Benefits Plan: Job Quality and Equity

The Community Benefits Plan document outlines our strategy to establish job quality and equity. The main elements of the plan are to: (1) conduct community listening sessions; (2) encourage the development of workforce and community benefit agreements; (3) establish the *Smart Grid Leaders Initiative* with local university partners, an initiative combining undergraduate scholarships, summer internships, and enrichment programs for electrical and computer engineering students to learn about and gain experience with grid enhancing technologies; and (4) offer training sessions to utility and labor organizations.

1.8 Strategy to Share and Maximize Benefits across Disadvantaged Communities

Disadvantaged communities will be encouraged to participate through information sessions, labor and business contracts, and the *Smart Grid Leaders Initiative* for students. The project will benefit these communities through decreased power costs, decreased environmental exposure, and increased payments to farmers and through community benefit arrangements from renewable generators. The project will also establish community-based emissions and electricity bill analysis capabilities to promote reduced cost of electricity benefits to end users.

1.9 Climate Resilience Strategy

Stability issues are caused when elements of the system become overloaded under contingency conditions, such as those caused by extreme weather or natural disasters. Anticipating future disruptions, the SmartValve technology operates in a "normally on" mode. When extreme weather or a natural disaster occurs, the presence of the SmartValves improves the system's ability to respond to the outages caused by these types of events, enabling post-fault transient recovery, helping to prevent further cascading system failures and enhancing system resiliency.

2. TECHNICAL DESCRIPTION, INNOVATION, AND IMPACT

2.1 Technical Feasibility

2.1.1 Previous Work and Prior Results

In 2012, Smart Wires, along with partners including Carnegie Mellon University and Georgia Tech Research Corporation, received $4M in ARPA-E (Advanced Research Projects Agency – Energy) funding to further develop this technology, including a control system, electrical and mechanical design, magnetic core, and packaging of its first-generation power flow control device for extreme environments. The ARPA-E grant was critical in providing Smart Wires funding to begin commercialization of its first product. Following laboratory testing under worst-case environmental and operational conditions, Smart Wires successfully demonstrated units in a Tennessee Valley Authority (TVA) field trial – 100 units deployed on a 161 kV transmission line (Knoxville, TN).[5]

The ARPA-E project team developed multiple power system models to identify opportunities to deploy Smart Wires technology, and compared those opportunities to conventional network investments. Preliminary system simulations by the ARPA-E team indicated that the devices have the potential to increase overall system utilization by more than 30%. This would allow utilities to significantly increase the capabilities of their existing infrastructure while safely deferring new transmission investment, resulting, in some cases, in a present value savings of over 80% relative to conventional transmission reinforcements. Beyond overload prevention and congestion management, other applications such as phase balancing appeared promising.[5]

A decade later, Smart Wires has engaged in deep strategic partnerships with some of the world's most respected utilities enabling Smart Wires to develop and deploy solutions responding to some of the power industry's most urgent needs—integrating more renewables; increasing grid capacity, flexibility and stability; reducing costs and environmental and community impacts; and preparing for an unpredictable future.

The past decade of product development has led to over 54 US patents and 40 filed abroad associated specifically with the functionality of the SmartValve device, while dozens more cover the communication and control system.[6] Table 1 highlights the primary patent families.

Table 1. Major SmartValve Patents

Family	Applicable Patents
Use of solid-state electronics (IGBTs) with bypass devices in SSSC applications	US10666038, US11309701, US20220158440 (pending), EP3646428 (pending), CN110770993 (pending), AU2018291792 (pending)
Impedance injection using distributed FACTS	US11121551, US20210384727 (pending), EP3614519, CN110858716 (pending), AU2019216584 (pending)
SSSCs in series and parallel configurations	US10756542, US10938210, EP3518366 (pending), EP3691069 (pending), CN110086174 (pending), CN111509698 (pending), AU2020200604 (pending)
Energy harvesting	US11095110

Controlled coordination of distributed FACTS devices	US11159046, US10218175, US10749341, US20200358288 (pending), US20210391747 (pending), CN109075577, EP3414811, AU2017218117
High speed communication of distributed FACTS devices	US10097037, US11063433, US10097037, US20210313806 (pending), EP3414577, EP3667855, AU2019271971 (pending)

2.1.2 Project's Access to Necessary Infrastructure

With the committed interest from both ComEd and AEP, the project team will have all necessary access to substation infrastructure, overhead lines, and other footprint required to site, prepare, assemble, and connect the SmartValve projects to the grid.

2.2 Innovation and Impacts

2.2.1 Current Standard Practice and/or State of the Art

Grid-enhancing technologies (GETs) maximize the transmission of electricity across existing systems through technologies that include sensors, power flow control devices, and analytical tools.[7] A 2022 DOE report on GETs found there is "ample opportunity to support existing grid infrastructure and alleviate existing transmission constraints, as well as future constraints from expected shifts in power supply and demand." Within the realm of GETs, SmartValve is a type of Static Synchronous Series Compensator Technology (SSSC) in the family of FACTS (Flexible AC Transmission System) technologies as shown in Figure 5. There is growing recognition of the potential of SSSCs in the US.

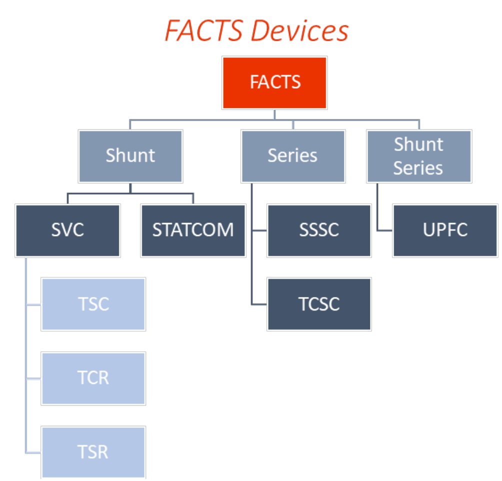

Figure 5. SSSCs are in the family of FACTS devices.

2.2.2 Specific Innovation of the Proposed Technology

SmartValve is a revolutionary, modular form of SSSC offering the next generation in the progression of FACTS. This digital power flow control technology quickly unlocks network capacity by reliably and autonomously pushing power off overloaded lines or pulling power onto underutilized lines. The SmartValve injects a leading or lagging voltage in quadrature (i.e., shifted 90 degrees) with the line current, providing the functionality of a series capacitor or series reactor respectively. However, unlike conventional series capacitors or reactors, the SmartValve can inject the voltage independently of the line current, thus increasing the effective reactance injection when operated below the rated current (Figure 6). SmartValve solutions are connected in series with the utility network facility, operate at line potential, and have no electrical connection to ground. This solution is particularly effective in highly meshed electric grids where spare system capacity can be utilized to resolve overload situations.

First Use. The deployment of the SmartValve technology in northern Illinois would be the first use of this technology in PJM, and the first time the technology is deployed specifically as part of bringing a new renewable energy facility on-line. The deployment in South Texas would be the first use of this technology in ERCOT, and the first time the technology is deployed specifically to provide transient stability support for greater renewable energy deliverability in the US.

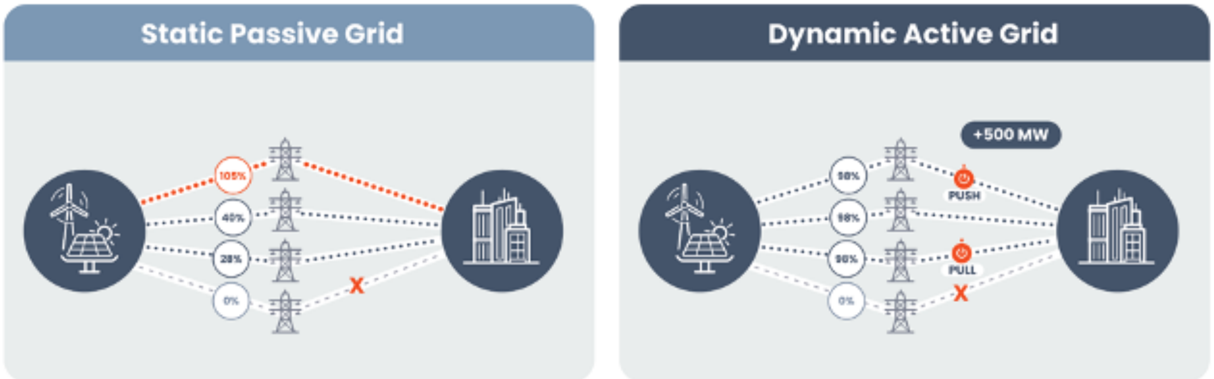

Figure 6. A conventional static passive grid (left) is contrasted with SmartValve (right), which is installed in series with transmission circuits to rebalance power across multiple lines and increase overall power transfer.

2.2.3 Comparison of Proposed Technology with Current and Emerging Technologies

Compared to other FACTS controllers, SSSCs are superior due to:[8] (a) elimination of bulky passive components such as capacitors and inductors; (b) ability to supply or absorb reactive power; (c) offers symmetrical inductive and capacitive operating modes; and (d) when connected with a DC power source on the DC side of an SSSC, they exchange real power to the power system. SSSCs can also connect to orenewable sources such as wind or any AC source.

Compared to other SSSCs, SmartValve's transformerless design offers a move away from custom engineering towards a modular, standard offering that reduces cost and size requirements, sometimes by 70% or more.[9] The flexibility in deployment of SmartValves means that installations can be tailored to meet specific substation or site restrictions. The devices can be stacked higher, laterally and/or split in different locations within the substation in response to substation spatial restrictions, making best use of available space and land. This is one of the key differentiating factors between SmartValve solutions and traditional power flow control solutions. SmartValve does not have the negative characteristics of past passive devices, such as the risk of SSR with series capacitors or the constant VAR consumption of series reactors. An EnerNex study of SmartValve impact on SSR found that active voltage injection from the SmartValve provides reactive compensation at line frequency like conventional series capacitors, but its actions do not extend to other frequencies.[10] Since the power transfer on a single line or through a network is determined by transient stability limits, deploying SmartValves thus improves system capability and flexibility, resulting in increased stability of the power system.[11] Other SSSCs require custom designs, series injection transformers, and considerable substation space.

SmartValve is compared with other technical solutions in Table 2.

2.2.4 Estimated Improvements in Performance of Proposed Systems

Northern Illinois. SmartValve deployment in this region will allow the **Shady Oaks 2 105MW generation facility to connect to the grid** enabling its environmental and community benefits to be realized. Due to the modular nature of the SmartValve technology, this deployment will be scalable in the future, allowing additional projects to interconnect to the system as well as **avoiding the need to build a $180M new transmission line** as a result of stability issues. Studies have shown that **at least 100MW of additional interconnection capacity** can be opened

Table 2. Comparison of SmartValve to other technical solutions.

	Core SmartValve Applications						Potential SmartValve Applications	
Solution	Thermal Overload Resolution		Transient Stability Improvement		Voltage Stability		Power Oscillation Damping	
SVC	✓[1] (green)	$ (green)	✓ (green)	$ (green)	✓ (green)	$[2] (green)	✓ (red)	$ (red)
STATCOM	✓ (green)	$ (green)	✓ (green)	$ (green)	✓ (green)	$[2] (green)	✓ (red)	$ (red)
SSSC	✓ (yellow)	$ (green)	✓ (yellow)	$ (green)	✓ (yellow)	$ (green)	✓[1] (yellow)	$ (green)
TCSC	✓ (green)	$ (yellow)	✓ (green)	$ (yellow)	✓ (green)	$ (yellow)	✓ (yellow)	$ (yellow)
UPFC	✓ (yellow)	$ (green)	✓ (red)	$ (green)	✓ (red)	$ (green)	✓ (red)	$ (yellow)
Series Reactor	✓ (green)	$ (red)	✓[1] (green)	$ (green)	✓[1] (green)	$ (green)	✓[1] (green)	$ (green)
Fixed Series Capacitor	✓ (green)	$ (red)	✓ (green)	$ (red)	✓ (yellow)	$ (red)	✓ (green)	$ (red)
PST < 20°	✓ (green)	$ (green)	✓ (yellow)	$ (green)	✓ (green)	$ (green)	✓ (yellow)	$ (yellow)
PST > 20°	✓ (yellow)	$ (red)	✓ (yellow)	$ (red)	✓ (green)	$ (green)	✓ (yellow)	$ (red)
Shunt Reactor	✓[1] (green)	$ (green)	✓[1] (green)	$ (green)	✓ (green)	$ (red)	✓ (green)	$ (red)
Shunt Capacitor	✓[1] (green)	$ (green)	✓[1] (green)	$ (green)	✓ (green)	$ (red)	✓ (green)	$ (red)
Batteries (General)	✓[1] (green)	$ (green)	✓ (green)	$ (green)	✓ (green)	$ (green)	✓ (yellow)	$ (green)
Line Uprating	✓ (red)	$ (green)	✓ (red)	$ (green)	✓ (red)	$ (green)	✓[3] (green)	$ (green)
New Line	✓ (red)	$ (green)	✓ (red)	$ (green)	✓ (red)	$ (green)	✓[3] (green)	$ (green)
DLR[1]	✓ (green)	$ (red)	✓[3] (green)	$ (red)	✓[3] (green)	$ (red)	✓[3] (green)	$ (red)
HVDC	✓ (red)	$ (green)	✓[3] (green)	$ (green)	✓ (green)	$ (green)	✓ (red)	$ (green)

Legend

- ✓ (green) SmartValve Technically Advantaged
- $ (green) SmartValve Cost Advantaged
- ✓ (yellow) SmartValve Technically Neutral
- $ (yellow) SmartValve Cost Neutral
- ✓ (red) SmartValve Technically Disadvantaged
- $ (red) SmartValve Cost Disadvantaged

1) This is not a typical application of this technology. For example, the main application of DLR is resolving thermal overloads, it tends to push systems toward all other limits and thus is disadvantaged or at best neutral to the SmartValve in all technical comparisons.
2) This is a location specific comparison, series compensation may be better for long lines.
3) This is not a core application, the cost comparison for this application is not likely relevant.

up by increasing the size of the initial SmartValve deployment in the future. (This 100MW would be in addition to the 300MW of benefits already associated with the project as a whole.)

LRGV. Based on the AEP's 2025 stability base case, the simulation showed that a total of 36 SmartValves opened up an **additional 186MW** flow in the Valley Export GTC. The GTC constraint was binding in 29% of the hours in 2022 and YTD in 2023. Therefore, on a yearly basis we estimate an additional 473GWh (186MW*8760*29%) of additional renewable generation will reach the grid each year as a result of the initial SmartValve deployment. Assuming that this additional renewable generation offsets fossil fuel based generation at a rate of 0.55 tons/MWh, **260,000 tons of CO_2 equivalent emissions would be avoided each year**. From a GWh perspective, approximately 6% of 7,000 MW of generation is curtailed in south Texas each year, equivalent to 1,472 GWh (8760*6% *.4). Thus, a total of 473 GWh of additional renewable generation reaching the market from the initial deployment represents a **32% reduction in curtailment levels**.

From a rate payer perspective, using 2022 shadow prices associated with LRGV regional constraints, we estimate—assuming that the value of relaxing the constraint stays constant across all 186MW—that the **value to ratepayers of the initial deployment in Texas would be $173M per year** (resulting from decreases in production costs on the system). Even if this number is reduced by half to account for anticipated reduction in marginal benefits across the 186MW, the resulting $86.5M per year still provides significant benefits that would lead to a payback period of less than one year.

2.2.5 Overall Impact on Advancing Technical Baseline if Project is Successful

Impact on the field and application. The grid's ability to adapt to the changing flow patterns needed to green the system is limited in part due to stability issues. Both of the deployments covered by this proposal use SmartValves to address transient stability issues in regions (PJM and ERCOT) and in contexts in which they have not previously been deployed: (1) specifically as part of bringing a new renewable energy facility on-line, and (2) providing transient stability support for greater renewable energy deliverability in the US.

Each system operator establishes their own practices, so it is impotant to demonstrate the use of the technology in each region to establish it as an accepted solution to be deployed in that jurisdiction to address these types of situations, which are expected to become more common as levels of renewable penetration increase.

Completion of these deployments will give additional tools to system operators and transmission facility owners who are looking for cost-effective solutions to integrate new renewable generation, and deal with stability constraints that simultaneously impact multiple transmission lines, without causing sub-synchronous resonance issues.

This initial deployment will provide a blueprint for PJM and transmission facility owners to apply SmartValve and other GET solutions. Generally a single generation project, or even a group of projects in PJM, cannot economically justify the cost of resolving dynamic stability issues through traditional solutions like building new transmission lines, so projects facing these issues do not proceed to interconnection. DOE funding of the northern Illinois deployment would demonstrate how to resolve these issues in a more cost-effective and timely manner, making connection of future renewables that face these concerns more likely to proceed.

The stability issues facing ERCOT occur wherever areas of significant renewable penetration are connected over relatively long distances to major load centers, creating the need to impose transmission constraints like the GTCs in ERCOT. Validation of this application on a single GTC in ERCOT will provide market certainty that cost-effective, relatively rapid solutions exist to this increasingly intractable problem.

Transmission projects are most often justified based on reliability. ERCOT has a process to approve transmission projects on an economic basis but it is seldom pursued. The last time an economically justified project was brought before the Regional Planning Group was in 2019. The DOE grant for the ERCOT project will be a catalyzing influence to bring together the stakeholders required to pursue a project through the economic justification process, advancing the field by providing a model for future projects and stakeholder groups to follow.

Development of training through the *Smart Grid Leaders Initiative* and for operators on dispatch methodologies and best practices will help advance the sophistication and performance of networks under complex circumstances. In turn, this will spur investment in both SmartValve projects and new renewable generation assets where similar problems have already or are likely to emerge in the near future.

2.2.6 Overall Economic and Environmental Impacts if Project is Successful

Economic and Environmental Impacts - Illinois. The initial Illinois implementation will avoid the necessity to construct a new $180M transmission line and immediately unlock the benefits of Shady Oaks 2 project. These benefits include: (1) reducing emissions on the Illinois grid by approximately 106,000 tons of CO_2 per year (the equivalent of removing 21,000 cars from the roads); (2) providing revenue to local farmers once the facility interconnects with the grid; (3) contributing over $1.1 million per year in property tax revenue; and (4) funding the already developed community benefits agreement with the village of Paw Paw, Illinois.

Beyond the immediate benefits from the initial deployment, because of its modular nature, the initial SmartValve solution can be scaled up in the future to accommodate additional renewable generation projects as they interconnect in the region, continuing to avoid the necessity to build a new $180M transmission line. (Currently, at least four renewable energy projects are proposed in the area.)

Economic and Environmental Impacts – Texas. It is estimated that initial Texas implementation can increase the transfer capacity through the LRGV Export GTC by 186MW, and by offsetting fossil fuel generation, 260,000 tons of CO_2 equivalent would be avoided annually. A total of 473 GWh of additional renewable generation would reach the market from the initial deployment, which represents a 32% decrease in renewable curtailments in south Texas. The value to ratepayers of the initial deployment on the Valley Export GTC is estimated at $173M per year (resulting from decreases in production costs on the system). The initial Texas implementation would also help to relieve the LRGV Valley Import constraint further benefitting ratepayers.

Approximately 16 GTCs are currently in operation across Texas. Assuming similar benefits can be derived from relieving other constraints, further deployment of SmartValve in Texas alone would be worth many times more to the system each year than the initial installation.

2.2.7 Relevance of Proposed Project to Goals and Objectives of the FOA

This FOA seeks applications to address three goals: (1) transform community, regional, interregional, and national resilience, including in consideration of future shifts in generation and load; (2) catalyze and leverage private sector and non-federal public capital for impactful technology and infrastructure deployment; and (3) advance community benefits.

The deployments proposed in this application support community decarbonization and grid resilience by allowing the incorporation of additional renewables onto the transmission system—and by helping to ensure the decarbonization and community benefits are realized once projects become operational. Not only will these deployments solve previously identified issues impacting late-stage generation projects and existing renewable operations, but they will also catalyze deployments of the technology to resolve similar issues across these regions.

2.2.8 Expected Project Outcomes

The deployment in Illinois demonstrates how increased renewables can integrate into the electricity grid without triggering the need to build new transmission lines in the face of stability issues. Deploying SmartValve technology on the existing Dixon-McGirr 138 kV transmission line will not only avoid the need for a new transmission line, but will also significantly reduce the time for new renewable projects to connect to the system. SmartValve is further designed to provide the system with a tool capable of autonomously and dynamically responding to system contingencies, helping to stabilize and increase the resiliency of the grid.

In the LRGV of Texas, the deployment of SmartValves on lines associated with GTCs is an innovative approach to alleviating existing transmission system congestion while maintaining system stability. Full deployment can be accomplished in a relatively short time compared to larger transmission construction projects. SmartValve installation will allow the system to make better use of the existing infrastructure, unlocking increased transmission capacity while maintaining stability in the region, reducing clean energy curtailments, supporting additional clean energy generation development in the area, and increasing the system's ability to respond to adverse contingency events.

2.2.9 Project's Access to a Skilled Workforce

The project will reinforce union labor selection and provide training for workers to grow their technical skill sets. Two higher education institutions will launch a *Smart Grid Leaders Initiative*, including a revamped electrical engineering undergraduate curricula to include Smart Grid topics, student scholarships and summer internships related to topics in high power engineering, and other enrichment opportunities with the aim of graduating students with knowledge and real-world experience in grid ehancing technologies.

2.3 Project Support for Resilience, Decarbonization, and Other Energy Initiatives

The deployments in both regions align well with state, regional, and national energy planning objectives. The proposed projects will demonstrate the benefits highlighted by various studies of GETs.[12] Implementation of these projects will provide a pathway to wider market adoption by demonstrating, in a short period of time, the benefits of implementing GETs and more specifically, the SmartValve modular SSSC technology by fully unlocking the physical capabilities of the existing grid. The project is in line with the state of Illinois's Climate and Equitable Jobs Act signed into law in 2021, which made it the first Midwestern state to commit to implementing a 100 percent carbon free electric grid by 2045. It also aligns well with the state of Texas 2021 legislation signed into law on improving ERCOT reliability.

2.4 Potential Impacts to Reduce Risk, Deploy At-Scale, and Obtain Private Investment

2.4.1 Reducing Risk

DOE funding will provide a significant endorsement for the wider adoption of the SmartValve technology, which has a proven track record of successful installations globally, but has been slow to be adopted in these US regions. Additionally, DOE funding will reduce the perceived new technology risk that can be pervasive among system operators and transmission asset owners. DOE support will help overcome the hurdles that any new technology has in being adopted in new jurisdictions, Increasing the rate of adoption of GETs (including SmartValves) in both regions.

2.4.2 Further Deployment

Successful implementation of this project will provide valuable replicable blueprints to resolve similar situations in PJM and ERCOT jurisdictions, as well as other areas. In the future, PJM's reformed queue process will help spread deployment costs across a larger number of projects as opposed to dealing with each project sequentially, increasing the opportunity for additional deployments of this technology. In the ERCOT market, the SmartValve deployment to help relieve the LRGV GTCs (2 of approximately 16 GTCs currently active in ERCOT) will be the first use of the technology to address this type of widely imposed constraint, and will serve as a significant catalyst to deploy the technology to relieve other constraints in the region.

2.4.3 Additional Private Sector Investment

To make informed decisions on the best path forward, the electricity industry undergoes an evaluation and learning period to establish the requisite knowledge base. Already, modular-

SSSC has passed through numerous stage gates set by utilities and system operators around the world, with commercial deployments in the UK, Australia, Colombia, and the US (Florida, Massachusetts, and New York). For example, in February 2022 the DOE acknowledged the viability and value of modular-SSSC in its Case Study on Ratepayer Impact report that also looked at the New York grid.[12]

The proposed deployment will establish a foothold for further SmartValve adoption in both the largest national regional transmission organization (PJM) and in the state with the highest penetration of renewable generation by GW (Texas). These initial installations will serve as catalysts to help unlock capacity for the sizeable PJM generation interconnection queue and towards addressing other GTCs in ERCOT. Successive deployments are expected to be funded with private sector investment, including generation developers that support further adoption of GETs. The American Clean Power Association (ACP) and its members have expressed full-throated agreement that SmartValve is a critical tool that must be incorporated into business-as-usual interconnection and transmission planning, most recently in public filings to the FERC Transmission Planning (RM21-17) and Generation Interconnection (RM22-14) Notices of Proposed Rulemaking (NOPRs).

2.5 Topic 2 (Smart Grid) Requirements Addressed in this Proposal

2.5.1 Relevancy to Topic 2: Objectives

*"In the case of advanced transmission technologies such as … **flow control devices**… **applied to existing transmission facilities** that **increase the operational transfer capacity of a transmission network**, and the **documented expenditures** to purchase and install those advanced transmission technologies."*

The total project cost is $85.8 million. Algonquin requests $42.9 million in DOE funds to purchase and install SmartValve technology in these two deployment cases. The 50 percent cost share of $42.9 million will be funded by the applicant.

The northern Illinois deployment consists of the purchase and installation of up to 12 SmartValve units (4 per phase) on the ComEd 138 kV Dixon-McGirr transmission line. The installation of the SmartValves will require substation modifications, including below-grade work for concrete foundations, erection of steel support structures, installation of the physical units, and associated communication and control devices. Critical Energy Infrastructure Information (CEII) restrictions limit the level of further technical details that can be released.

The LRGV Texas deployment consists of the purchase and installation of 36 SmartValves units on two of the interface lines associated with the LRGV Valley Export and Import GTCs, the Ajo-Nelson Sharpe 345kV line and the North Edinburg-Lon Hill 345kV line. Installation of the SmartValves on these lines will require substation modifications, including below-grade work for concrete foundations, erection of steel support structures, installation of the physical units, and associated communication and control devices.

2.5.2 Relevancy to Topic 2: Priority Technical Approaches

*"Increasing **transmission capacity and operational transfer capacity** through grid enhancing technologies such as dynamic line rating, **flow control devices**, advanced conductors, and network topology optimization, to improve system efficiency and reliability."*

Through deployment of SmartValves, an innovative digital power flow control device in the form of a modular SSSC, the project will significantly increase the effective transmission capacity and the operational transfer capacity on the Illinois Dixon-McGirr 138 kV transmission line and the operational transfer capacity across the Valley Export and Import GTC's in South Texas. The increased capacity in northern Illinois will unlock the ability to integrate **105MW initially, and at least 100 MW of additional generation** in the future in northern Illinois with additional expansion, enhancing the operational transfer capacity and resiliency of the system. The deployment in ***Texas*** will increase the operational transfer capability of the system across the LRGV Valley Export constraint by approximately **186MW**, helping to reduce the 6% of potential generation that is currently being lost in south Texas due to renewable curtailments. Additionally, the Texas deployment will increase the capacity of the system to integrate future renewable facilities, and also help to relieve the LRGV Valley Import constraint, which will improve the ability to get power to consumers when the local renewable facilities are not generating. Compared to traditional solutions like building new transmission lines, SmartValves will significantly reduce cost, provide dynamic and autonomous control, and improve system efficiency and reliability.

*"Improving the **visibility of the electrical system to grid operators**, to **help quickly rebalance the electrical system with autonomous controls**, through data analytics, software, and sensors."*

SmartValve is installed in series with existing lines to provide greater available transmission or distribution network capacity. It does this through either injecting a leading or lagging voltage in quadrature with the line current, providing the functionality of a series capacitor or series reactor respectively. Capable of dynamic and autonomous control, the Smart Valves provide another tool to grid operators helping to quickly rebalance the electrical system. Additionally, SmartValve does not have the negative characteristics of past passive devices, such as the risk SSR with series capacitors or the constant VAR consumption of series reactors.

*"**Anticipate and mitigate the impacts of extreme weather or natural disasters** on grid resiliency, including investments to increase the ability to redirect or shut of power to minimize blackouts, prevent wildfires, and avoid further damage."*

Stability issues are caused when elements of the system become overloaded under contingency conditions such as extreme weather or natural disasters. Anticipating future disruptions, the SmartValve technology operates in a "normally on" mode. When contingency conditions occur, the presence of the SmartValves improves the system's ability to respond to outages enabling post-fault transient recovery, helping prevent further cascading system failures.

3. WORKPLAN

3.1 U.S. Infrastructure and Buy America Requirements

The project will involve the construction, alteration, maintenance and/or repair of utility infrastructure in the US, although the substations and lines are owned by private entities. Additionally, the prime recipient is a for-profit entity, so the Buy America requirements do not apply. All collaborators will be urged to source from domestic entities insofar as possible.

3.2 Project Objectives

The objectives of the Technical Program include:

- Increase transmission capacity and operational transfer capacity of the grid, which in turn maximizes the system's ability to absorb and use renewable generation without curtailments;
- Successfully install the SmartValves;
- Improve the visibility of the electrical system to grid operators, to help quickly rebalance the electrical system;
- Reduce barriers to wider use of advanced power flow control (APFC) technology on the US transmission grid; and
- Reduce the financial and pollution energy burden for marginalized customers.

The objectives of the Community Benefits Plan are to engage with the community and labor, educate and train a diverse workforce, create new jobs leading to long-term careers, reduce utility costs to end users, and reduce fossil fuel usage while increasing energy resilience.

3.3 Project Scope Summary

Phase 1: Technical Planning. Prior to implementation, two key tasks to prepare for field installation are: 1) approvals and permits, and 2) engineering and procurement. The SmartValve technology is in an advanced stage, having passed technology due diligence and initial solution sizing stage gates. The host utility will identify preferred SmartValve operational settings.

Phase 2: Technical Implementation. The implementation phase includes site preparation, SmartValve installation, commissioning, and in-service operation. The installation task includes training for system operators, including integration and operation within supervisory control and data acquisition (SCADA) and energy management system (EMS) architecture. Commissioning will validate that device performance in the field matches that at the assembly facility, including testing the functionality of the SmartValve to inject capacitive and/or inductive voltage into the network and change power flows.

Implementation of Community Benefits Plan. Our plan will inform labor, business, and communities of project opportunities and benefits through community listening sessions. We will encourage workforce and community benefit agreements. University subawards will offer advanced curriculum and fund undergraduate scholarships and summer internships. Training sessions will be offered to utility and labor organizations. We will research and analyze the impact of the installation on end user utility bills and present results in a white paper.

3.4 WBS and Task Description Summary

The seven major WBS and Task descriptions are summarized below, and presented in detail in the Statement of Project Objectives (SOPO) document:

- Task 1.0 – Project Management and Planning (months 1-54)
- Task 2.0 – Approvals and Permits (months 1-8)
- Task 3.0 – Engineering and Procurement (months 1-15)
- Task 4.0 – Installation (months 15-21)
- Task 5.0 – Commissioning (month 22)
- Task 6.0 – In-Service (months 23-24)
- Task 7.0 – Implementation of Community Benefits Plan (months 1-54)

3.5 Tasks, Schedule, and Milestones

The SmartValve deployment schedule for Tasks/Subtasks 1-6 and milestones are shown in Table 3; milestone completion dates are indicated by diamonds, smart milestones by stars, deliverables by “D”, and M=month. The darker colors indicate the full term of a task and its subtasks, while the lighter colors indicate the duration of the respective subtasks only. Full descriptions are given in the SOPO.

Table 4 presents the Community Benefits implementation schedule (Task 7), where Q =quarter; note that *for purposes of managing Task 7 only*, Task 1 will extend from month 25 to month 54.

3.6 SMART Go/No-Go Decision Points (DPs) (see Table 1 of the SOPO for full description)

DP 1. Installation and line connection design achieves at least 30% completion status (M9).
DP 2. SmartValve line current and injection performance meet acceptaince criteria (M22).
DP 3. Stakeholder Committee decides whether to continue scholarship program (M37).

3.7 End of Project Goal

For **technical project** goals, In-service testing will verify that under planned system conditions the SmartValve devices achieve operational parameters as expected at both locations, enabling predicted system benefits. For **community benefits** goals we will verify: (a) community and labor engagement through participation of at least 50 representatives at information sessions, and executed agreeements; (b) 20 student scholarships under *Smart Grid Leaders Initiative* awarded; and (c) reduced end user utility cost and emissions to the community, verified by student researchers.

3.8 Project Management

3.8.1 Organization and Reporting Structure

As shown in Figure 7, the prime recipient of the project is Algonquin Power Fund (America), Inc. (blue box), which will report to the Federal Project Officer of the GDO/OCED office of DOE. Algonguin’s project personnel will be under the direction of Mark Phelan as Project Manager. The Project Manager also will chair the Stakeholder Committee and interface with SmartWire, while the Community Benefits manager will oversee subawards to the University of Texas and University of Illinois (green box). Finally, the collaborating partners are summarized in the yellow box. A number of organizations have provided **Letters of Support**.

Table 3. Project Tasks 1-6, Subtasks, and Milestones

SmartValve Deployment Schedule																								
Tasks, Subtasks, and Milestones	Year 1												Year 2											
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Task 1.0 - Project Management and Planning																								
Subtask 1.1 - Project Management Plan (PMP)	D																							
Subtask 1.2 - National Environmental Policy Act (NEPA) Compliance	D																							
Subtask 1.3: Cybersecurity Plan (CSP)	D																							
Subtask 1.4: Continuation Briefing(s)												D												D
Task 2.0 - Approvals and Permits																								
Subtask 2.1 - Purchase Order Milestone 2.1.1 – Purchase order received by Smart Wires	◇																							
Subtask 2.2 - Land Acquisition Milestone 2.2.1 – Land title(s) acquired (if necessary)				◇																				
Subtask 2.3: Environmental Permitting Milestone 2.3.1 – Environmental permits acquired (if necessary)								◇																
Task 3.0 - Engineering and Procurement																								
Subtask 3.1 - Advanced Studies																								
Subtask 3.2 - Long Lead-Time Ordering Milestone 3.2.1 - Long lead-items ordered						◇																		
Subtask 3.3 - Installation and Line Connection Design Milestone 3.3.1 – 30% design completed Milestone 3.3.2 – 60% design completed									◇															
Subtask 3.4 - Device Manufacturing Milestone 3.4.1 – End-of-Line (EOL) test reports completed															☆									
Task 4.0 - Installation																								
Subtask 4.1 - Site Preparation Milestone 4.1.1: Site readiness report complete																◇								
Subtask 4.2 - Equipment Installation, Milestone 4.2.2: Post-installation report complete																					◇			
Task 5.0 - Commissioning																								
Task 5.1 - On-site Commissioning Milestone 5.2.1: Commissioning report accepted by host utility																						◇		
Task 6.0 - In-Service																								
Task 6.1 - In-Service Testing Milestone 6.1.1: In-service test report complete																								◇

Table 4. Community Benefits Plan Task, Subtask, and Milestones

Task, Subtasks, and Milestones	Year 1				Year 2				Year 3				Year 4				Year 5	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18
Task 7.0 Community Benefits Plan Implementation																		
Task 7.1 - Workforce and Community Benefit Agreement Negotiation Milestone 7.1.1: Agreements executed (M6)		◇																
Task 7.2 - Community Listening Sessions Milestone 7.2.1: 4 community listening sessions conducted (M10)				◇														
Task 7.3 - Undergraduate Scholarships Milestone 7.3.1: 20 undergraduate scholarships awarded (M10) Milestone 7.3.2: Ave. 90% satisfaction rating from student participants (M25) Milestone 7.3.3: Ave. 90% satisfaction rating from student participants (M37) Milestone 7.3.4: Ave. 90% satisfaction rating from student participants (M49) Milestone 7.3.5: 20 undergraduate scholarships fully subscribed (M54)				◇					☆				☆				☆	◇
Task 7.4 - Undergraduate Summer Internships Milestone 7.4.1: 20 undergraduate summer internships secured (M46)																◇		
Task 7.5 - Utility and Labor Organization Training Sessions Milestone 7.5.1: Training sessions completed (M15)					◇													
Task 7.6 - Electricity Bill Research and Analysis. Milestone 7.6.1: White paper on SmartValve impact to electric bills (M15)								◇										

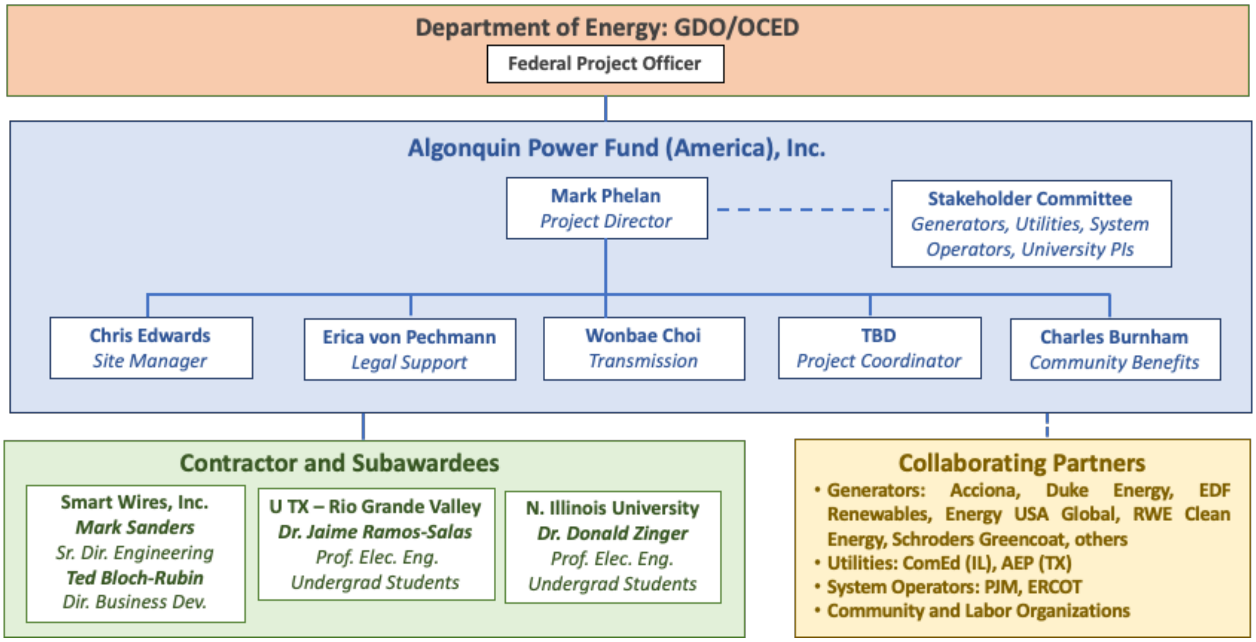

Figure 7. Project Organizational Chart

3.8.2 Roles of Project Team Members

Table 5 summarizes the expertise and roles of the Project Manager and Project Team, who have the skill and expertise needed to successfully execute the project plan.

3.8.3 Communication Plan

Algonquin and Smart Wires personnel will initially meet weekly via Microsoft Teams to coordinate technical activities and report progress, then biweekly during the first two years of the project until the SmartValve installations are complete.

The *Stakeholder Committee*, comprised of utilities, system operators, affected generators, and university Principal Investigators (PIs), will meet quarterly for the first two years of the project to coordinate activities. In addition, information sessions will be held for community, labor, and business organizations as described in the Community Benefits Plan. This Plan also provides details on the *Smart Grid Leaders Initiative* to train future leaders through two collaborating universities. The university subawards will extend 2½ years beyond the 2-year SmartValve technical project (4½ years total).

3.8.4 Financial and Project Management Practices

Algonquin has well established financial management practices and follows US GAPP in its reporting practices. From a financial controls perspective, the company has a fulsome delegation of authority policy, with signing authority determined by the role of each person in the organization and stage of project. Budgets for all capital projects are set at project initiation. A financial work order is set up to enable cost reporting on a project-by-project basis, and an industry standard cost element structure is used to further break down and track project expenditures. As well as a Project Manager, each project has a Project Coordinator who is responsible for project level accounting and this activity is overseen by the Senior Manager of Project Controls. In addition to the team meetings, Algonquin's internal regular reporting

Table 5. Senior/Key Personnel and Project Roles

Name and Title	% FTE	Role in Project	Expertise
Mark Phelan, Director Greenfield Development, Algonquin	50%	**Project Manager and Technical Point of Contact**: Oversees technical implementation and reports on project to stakeholders; chairs Stakeholder Committee, reports to DOE	Utility scale renewable project origination, acquisition, development, and financing; coordinating cross-functional teams and consultants; controlling budgets
Charles Burnham, Director of Government Affairs, Algonquin	25%	**Community Benefits Manager**: manages, coordinates implementation of Community Benefits Plan, oversees university programs.	Stakeholder management and outreach, government lobbying, energy policy and legislation
Chris Edwards, Manager Construction Site, Algonquin	100%	**Site Manager and Business Point of Contact**: oversees project site work for Algonquin on both deployments	Permitting and building codes; construction planning and scheduling; safety, compliance, and QA/QC management
Wonbae Choi, Director, Transmission and Interconnection, Algonquin	10%	**Technical Support**: performs technical studies; interfaces with AEP, consultant submissions for ERCOT, PJM, and Commonwealth Edison; provides technical support for interconnection and construction.	Electrical engineering, transmission planning and generation interconnection, power system simulation software, produc-tion cost modeling software,ISO/RTO/FERC tariffs,rulemaking
Project Coordinator (TBD) Algonquin	100%	**Project Coordinator**: project cost tracking, financial reporting, and administrative support	Document control management, project and construction planning and scheduling, financial reporting
Erica von Pechmann,Esq., Director, Legal & Business Affairs, Algonquin	10%	**Legal Support**: negotiates construction agreements, interconnection agreement (Illinois), any additional funding agreements (Texas)	Background in acquisition, disposition, financing, tax equity, and offtake transaction of renewable energy projects
Mark Sanders, Senior Director of Engineering, Smart Wires Inc.	25%	**Contractor for Smart Wires:** Provides technical expertise, interfaces with partners to provide design, installation, & construction assurance	Civil engineering, team management, high voltage transmission and substation design, renewable technologies.
Ted Bloch-Rubin, Director Business Development, Smart Wires	25%	**Contractor for SmartWires**: Assists implementation of Community Benefits Plan, assists with university programs.	State and federal energy policy, stakeholder management, civil, mechanical, and environmental engineering
Dr. Jaime Ramos-Salas, Professor, Electrical Engineering, U TX – RGV	10%	**Principal Investigator**: recruit students, award scholarships and summer internships, course development, coordinate seminar series.	Electric power systems, renewable energy, energy efficiency, engineering education
Dr. Donald Zinger, Professor, Electrical Engineering, Northern Illinois University	10%	**Principal Investigator**: recruit students, award scholarships and summer internships, course development, coordinate seminar series.	Alternative energy, power electronics, Lighting, Electric Machine Control, Industrial Controls, Engineering Education
Student Scholars & Interns, U TX – RGV and N. IL University	100% SU	**Scholarship awardees/summer interns**: study impacts of SmartValve on performance, end user cost; studies, other	Undergraduate electrical and computer engineering students

practices include: holding a monthly project meeting; producing a monthly written report that summarizes progress and issues on all projects for senior management and the CEO; and presenting a quarterly construction report to the Board of Directors. Performance incentives are in part tied to successful completion of projects on time and on budget.

Algonquin follows a rigorous standardized process for project management, the APMM (Algonquin Project Management Methodology). This process has five stage gates covering stages of early development through construction and the final project hand off to operations. Each project has a Project Manager with overall responsibility for the project, a Project Coordinator for administrative and project accounting responsibilities, and for projects under construction, a Site Manager to ensure contactor work at the site proceeds safely and according to plan, as well as other team members critical to the success of the particular project. In addition to the assigned project team, Algonquin has internal experts in areas such as permitting, stakeholder relations, and transmission interconnection that the project team draws on to manage specific scopes of workand specialist consultants.

3.8.5 Risk Management Plan

The potential risks to the project identified at this time are summarized in Table 6.

Table 6. Risks to the project

Risk Description	Risk Probability	Risk Impact	Risk Score	Mitigation Plan
Project delays due to manufacturing time for equipment and material availability.	Medium	Medium	Medium	To the extent possible, long lead time materials will be ordered with a 30% margin on time to mitigate supply chain induced delays.
Project delays due to delays in obtaining required permits.	Low	Medium	Low	Illinois location has Special Use Permit in place; no additional long lead time permits are expected. Texas locations are in existing substations, thus no additional long lead time permits are expected to be required.
If an alternative site is needed, this may result in land acquisition costs and permitting delays.	Low	Medium	Low	Project sites have been identified with ComEd and AEP that have existing space for device installation. Land acquisition costs are budgeted as a contingency.
Major equipment may be delivered at site with physical damage.	Low	Medium	Low	Smart Wires utilizes transportation partners that prioritize the physical integrity of our devices in transit to site.
Unforeseen device functionality issues	Low	Medium	Low	A commissioning spares plan will be created.
Cost overruns due to scope changes or commodity/labor costs.	Medium	Medium	Medium	Fixed price contracts will be negotiated with contractors. Scope changes will be minimized through diligent project management.

The Project Manager or designee will regularly update and maintain a risk registry with mitigation plans and how issues were resolved. As far as we are aware at this time, the project team anticipates successful deployment within the target timeframe and schedule.

3.8.6 Handling of Project Changes

The Project Manager or designee will keep a dated log of project changes, including: (a) the reason for the change, (b) impacts to schedule, budget, and personnel (as applicable), (c) plans for mitigation (revisions), (d) references to communications and documentation, and (e) approval of the change(s) by DOE, if required. Any significant changes and their effects will be discussed in the regular team meetings and revised plans will be generated.

3.8.7 Approach to QA/QC, if applicable

Smart Wires is ISO-9001 compliant, as is its manufacturing partner JABIL. Smart Wires establishes standards for (a) Quality Control, (b) First Article Inspection (FAI), and (c) In-process Test requirements and controls. A Control Plan is reviewed for each installation to document the actions, measurements, inspections, quality checks and monitoring of process parameters required at each phase of a process step to assure the process outputs will conform to pre-determined requirements. The Control Plan is used in conjunction with an inspection sheet or a checklist, and also includes supplier quality assurance and post-mortem inspection. It is a living document that will be periodically updated throughout the life cycle of the SmartValve.

4. TECHNICAL QUALIFICATIONS AND RESOURCES

4.1 Existing Equipment and Facilities

The **Smart Wires headquarters** includes extensive laboratory space for high-current testing and Real Time Digital Simulator (RTDS) analyses, both of which enable SmartValve installations for utilities around the world. Smart Wires manufacturing partner, JABIL, is located in St. Petersburg, Florida, and has specialized in SmartValve assembly for over 3 years.

The SmartValve installations at both the LRGV and Northern Illinois sites will leverage primarily existing substation infrastructure for their deployment. The combination of security fencing, ground grid, readily available overhead line connections, and on-site communication and control equipment make substations ideally suited for SmartValve installations, echoing why nearly all SmartValve installations to date have been sited at or adjacent to existing substations.

4.2 Justification for New Equipment or Facilities

SmartValves are typically supported from below by transmission-class post insulators. They may be stacked vertically up to 2 devices high. No component of the SmartValve solution emits large magnetic fields like an air core reactor. Therefore, there are no layout constraints between the SmartValves and adjacent metallic structures to avoid the induction of eddy currents in the adjacent metallic structures. Layout flexibility allows for creative utilization of existing substation footprint and overhead line connections. Some utilities install a circuit breaker or switch and an electrical bypass in parallel with SmartValves on a given circuit. This eliminates the need to mobilize a crew to restore the circuit should the SmartValve solution lose continuity, which is highly unlikely. This also reduces or eliminates the need for a line outage to commission and maintain SmartValves. Other components that may be required for a typical SmartValve installation include wood poles, conductor, interconnection compression fittings, clamps, t-taps, strain insulators (for breaking conductor), surge arresters, concrete, and rebar.

Aside from civil, structural, electrical, and mechanical engineering design activities associated with installation, on-site preparation in advance of SmartValve installation may include reinforced concrete foundation pours, transmission-class post insulator installation, overhead line or electrical bus connection support structure erection, communication equipment installation, and assorted pre-commissioning test activities.

4.3 Relevant Previous Work

Algonquin projects include substation work that will be similar in scope to the activities in this project, in addition to many other complex aspects involved in developing, permitting, and constructing renewable energy facilities. SmartWires and Algonquin have been engaging in project identification and solution development activities for the past 18 months on issues affecting development projects and operating generation assets across North America. Algonquin project team members have worked with PJM and ERCOT on interconnection of six previous generation projects.

4.4 Time Commitment of Key Team Members

The time commitments of key team members are shown in Table 5.

REFERENCES CITED

[1] US Department of Energy, "Grid Enhancing Technologies: A Case Study on Ratepayer Impact," February 2022

[2] The Brattle Group, "Unlocking the Queue with Grid Enhancing Technologies," February 2021

[3] https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-australia-report

[4] https://www.eia.gov/tools/faqs/faq.php?id=92&t=4#:~:text=How%20much%20of%20U.S.%20energy,total%20utility%2Dscale%20electricity%20generation

[5] https://arpa-e.energy.gov/impact-sheet/smart-wires-geni

[6] https://www.smartwires.com/patents

[7] https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

[8] https://resources.system-analysis.cadence.com/blog/msa2021-the-structure-characteristics-and-advantages-of-ssscs

[9] "Improving Transfer Capability Without Series Compensation Challenges," available on www.smartwires.com

[10] "Comparative Performance of SmartValves with EHV Series Capacitor: Implications for Sub-Synchronous Resonance," is available on www.smartwires.com

[11] "Improving Transfer Capability Without Series Compensation Challenges," available on www.smartwires.com

[12] US Department of Energy, "Grid Enhancing Technologies: A Case Study on Ratepayer Impact," February 2022.