SmartValve
Pilot Project 2016

SMART WIRES

EIRGRID

The last decade has seen a major increase in the levels of electricity generated from renewable sources

A shared vision for a dynamic and more flexible grid

Smart Wires and EirGrid are working together to transform electricity grids forever. In response to rapid changes in the electricity sector, we have been on a journey together to find new solutions to new challenges.

The last decade has seen a major increase in the levels of electricity generated from renewable sources like wind. While this is a welcome step away from carbon, this change creates new challenges when operating the electricity grid.

Electricity from renewable sources is not always available when and where it is needed. Also, unlike legacy forms of generation, renewables do not deliver a predictable, continuous flow of power. These characteristics create considerable challenges for electricity grids all over the world.

This evolution in electricity generation comes at a time of other changes in the sector. There is rapid growth in the capacity demanded by high-tech customers like data centres. There is also the potential for rapid change in domestic consumption patterns due to electrification of heat and transport.

And accompanying these seismic shifts, there has been a sea change in public acceptance of new electricity infrastructure. The path to acceptance and consent is now long and uncertain - a challenge that is common to all large-scale infrastructure projects.

Grid operators now need to become more efficient. They also need to add flexibility and responsiveness to existing transmission infrastructure. EirGrid, in particular, made a public commitment about these issues in its 2014 grid strategy. Then company committed to develop and improve the grid while minimising the impact on local communities.

A key component of this strategy was more engagement with stakeholders – including technology partners such as Smart Wires.

Demonstrating a new technical solution to deliver this vision

Smart Wires is dedicated to optimising the way power flows in existing grids using new and innovative technologies.

This new thinking will lead to more dynamic grids using solutions that are clean, reliable, affordable and safe. Working with EirGrid – the grid operator for Ireland – Smart Wires is developing and testing these ideas.

This report provides information on one such idea: SmartValve™.

This technology delivers two key benefits. It allows power to be pulled onto lines with spare capacity. But it also pushes power away from congested lines to other lines on the system with spare capacity.

This builds on the Smart Wires Guardian™ device – which first showed the viability of pushing power. This family of products offers a new solution. It allows grid operators to manage power flows by dynamically adjusting the reactance of electricity lines. The Smart Wires family of products can now prevent system overload dynamically and in real time.

EirGrid has been partnering with Smart Wires to test these new technologies since 2015. At that time, the Smart Wires Guardian product was successfully installed on a line in Cullenagh, County Waterford.

In 2016, EirGrid and Smart Wires collaborated to deliver the first ever installation of SmartValve on a live power system. Three SmartValve units were installed on towers at two substations on the Cashla - Ennis 110 kV linen in the west of Ireland. This provided EirGrid the ability to increase or decrease reactance to change power flow control in real-time.

Crucially, this was added to a live system without affecting local residents.

This report summarises the results of this pilot project. Its success will allow EirGrid to plan for the potential future use of this technology. As the operator of a compact-sized island system, EirGrid has had the courage and capability to respond to new ideas like SmartValve.

The success of this SmartValve pilot project sets a marker that other grid operators around the world can now follow. It clearly demonstrates the potential to deliver a renewed, more flexible and more dynamic grid.

The Smart Wires family of products can now prevent system overload dynamically and in real time.

EirGrid Group

EirGrid Group is responsible for a safe, secure and reliable supply of electricity – now and in the future.

We develop, manage and operate the electricity transmission grid through EirGrid in Ireland and SONI in Northern Ireland.

Our transmission grid brings power from where it is generated to where it is needed throughout Ireland and Northern Ireland. We use this grid to supply power to industry and businesses that use large amounts of electricity.

Our grid also powers the distribution network. This supplies the electricity used every day in homes, businesses, schools, hospitals, and farms.

EirGrid Group includes SEMO - the Single Electricity Market Operator. SEMO operates the wholesale electricity market across the island of Ireland.

EirGrid Group also owns and operates the East West Interconnector, a high-voltage link between the electricity grids in Ireland and Great Britain.

EirGrid Group is world-leader in the integration of renewable energy on the grid. In 2016, the amount of wind-generated electricity on our system reached a peak of 78% of demand.

EirGrid is now leading a Horizon 2020 European Union (EU) Research and Innovation project worth over €20m. This will facilitate the integration of renewables in Europe. This will allow Ireland – and the EU – to realise renewable energy goals into the 21st century.

Smart Wires

Smart Wires designs and manufactures advanced power flow control technology for electricity systems. We are fast becoming the industry leader for innovative grid solutions in Europe.

Our vision is to create dynamic transmission grids across the world that are clean, reliable, affordable and safe. We aim to achieve this vision by transforming the way grids are planned and operated.

This transformation is powered by innovative technologies for the electricity sector. These technologies address the rapidly evolving challenges of today and tomorrow.

In particular, our solutions help our partners to manage the flow of power through their grids in real-time.

We achieve this with products that optimise power flow on existing lines with minimal environmental or local impact. This reduces the need to build expensive new lines.

Smart Wires products also make it easier to connect more renewable energy sources to the grid. This helps our partners to design sustainable electricity systems that guarantee the future of the grid.

What is SmartValve™?

SmartValve is an innovative new device that enables real-time power flow control on grids. It uses series compensation to increase or decrease reactance of a line, which causes power to be pushed away from or pulled onto the line. This effectively diverts current from overloaded lines to underutilised ones.

The end result is an increase in the amount of power that can safely be carried by a set of lines. The change in reactance can increase typical flows through a set of lines by up to 30%. The only limit is the physical capacity of existing infrastructure.

SmartValve works by using power electronic equipment to inject a specific voltage in series with the line. When the devices inject this voltage in series they are said to be in "injection mode". When the devices are not injecting a voltage in series with the line, they are said to be in "monitoring mode".

The devices can be cycled from monitoring mode to injection mode automatically, or manually by the operator.

A SmartValve device can be applied to all three phases on a circuit, depending on the amount of flow change desired.

SmartValve has advantages over traditional series compensation / power flow control devices.

It is a light and modular technology that can be installed on towers, in banks or at substations. It is quick to install and uninstall, allowing the solution to be scaled or moved as the needs of the grid change.

This makes SmartValve a sustainable, efficient and cost-effective way to optimise how power flows through a grid.

EirGrid is committed to optimising the network to minimise requirements for new infrastructure. SmartValve is one technology that has the potential to help EirGrid achieve this.

Aims of this pilot for SmartValve for EirGrid

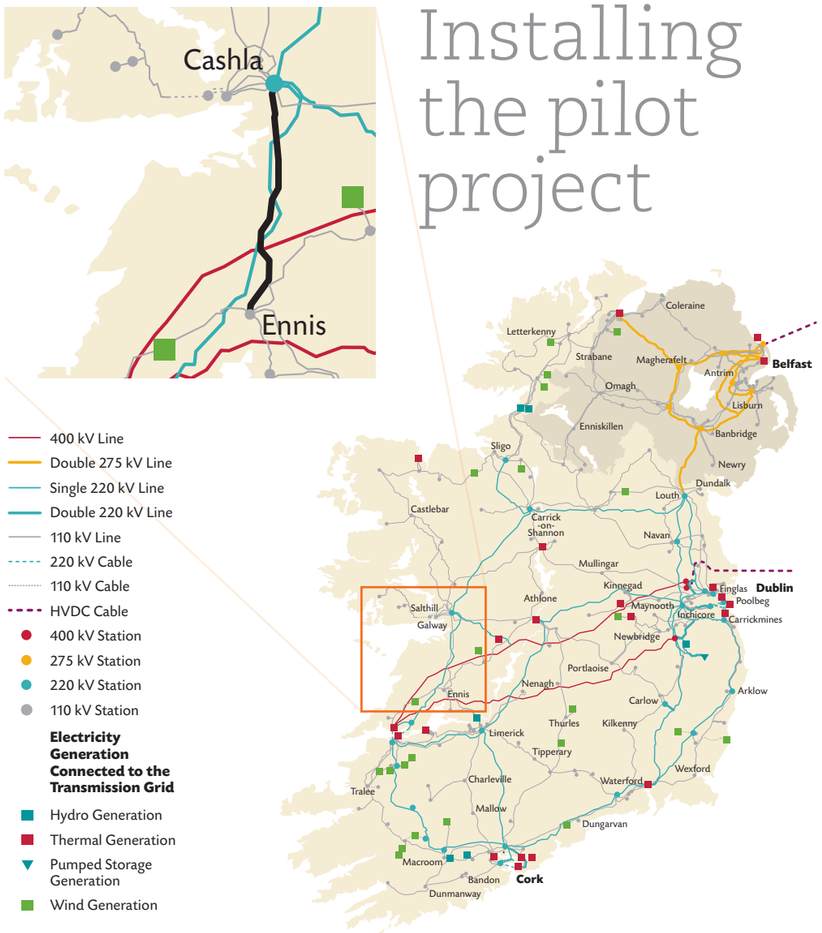
In 2016 EirGrid launched a pilot project with Smart Wires. The aim of this pilot was to demonstrate that SmartValve could operate as expected for one year on the live grid.

EirGrid sees the potential of power flow technology to help meet the future needs of the grid. This pilot allowed for a live testing of the technology to inform future decisions about its wider use throughout the grid.

Trial Installation – June 2016

For the pilot project, three SmartValve units were to be installed on the Cashla – Ennis 110 kV line. This decision took into account the capacity of existing towers to accept the weight of the units. The analysis also considered extreme environmental conditions like high winds and ice loading.

Installing the pilot project



As a first step, one of the three units was installed on a newly built – but not yet energised – line at a substation in Kinnegad, County Westmeath.

This was effectively a trial installation. This allowed the project team to gain operational experience of installing the unit safely.

The asset owner determined the safest way to locate the machinery required to raise the unit to the tower. The project team also considered how to bring the linemen up to the working level of the tower. This process took just over an hour during the trial installation.

The trial installation took place on 29 and 30 June 2016. This unit was then dismounted ahead of the full installation on the Cashla – Ennis line on 27 July 2016.

Full Installation – October 2016

Two SmartValve units were installed on the first tower coming out of the Cashla substation in County Galway. The remaining unit was then installed on the first tower coming out of the Ennis substation on the same circuit.

The first unit at Ennis took approximately five hours to install. Although it only took about 15 minutes to attach the unit, the process revealed an issue with the length of the jumper leads on the device.

During trial installation, it was necessary to extend the jumper leads. This was to accommodate an insulator between the body of the device and the jumper.

On site, it was found that further additional extensions were required. These were fabricated at the site before being fitted at the tower. This took just over two hours

The installation of the two units at Cashla took around 3 and a half hours in total. The units were first installed on their respective crossarms. They were then subsequently attached to the jumpers. Moving the installation equipment from one side of the tower to the other took approximately 30 minutes.

A 50 ton press up and an electrical generator were required to assemble the jumpers that were then attached to the jumper flags on each unit. This took between 20 and 30 minutes for each installed unit.

An assessment of the pilot project

Installation	Install three SmartValve units and associated telecommunications and software systems.	Result: **Success**
Commission and Acceptance Testing	Verify that communications with SmartValve units do not impact systems used to report primary faults. Verify that the SmartValve units can change reactance as specified.	Result: **Success**
Operational Testing	Test the SmartValve units in live use and against operational standards. Assess availability and reliability of the units under conditions essential for grid infrastructure.	Result: **Success**
Functional Testing	Assess the full functional performance of the SmartValve units. This includes switching units from full Capacitive Reactance Injection mode to full Inductive Reactance Injection mode.	Result: **Success**

Operational Testing

EirGrid tested key operational measures over the one-year pilot period. This included assessing the availability and reliability of the units.

The Availability Metric was key. Availability measures the percentage of time the units were communicating – with no more than a 60 second lag between each scan.

The SmartValve units had a 99.9% availability when in monitoring mode and in injection mode.

During this period, data was transferred from each SmartValve unit every 10-15 seconds to the server. This data could then be stored for off-line analysis and assessment of the operating performance.

Communication and Control

The SmartValve units were controlled through the Smart Wires communications platform. This allowed EirGrid to inspect the location and availability of the SmartValve units.

This also allowed the unit to be switched into injection mode, and to inspect system parameters – including line current and line temperature. This information is highly useful to grid operators. This is especially the case in situations where the grid is being impacted by weather events, or other unusual situations.

Functional Testing

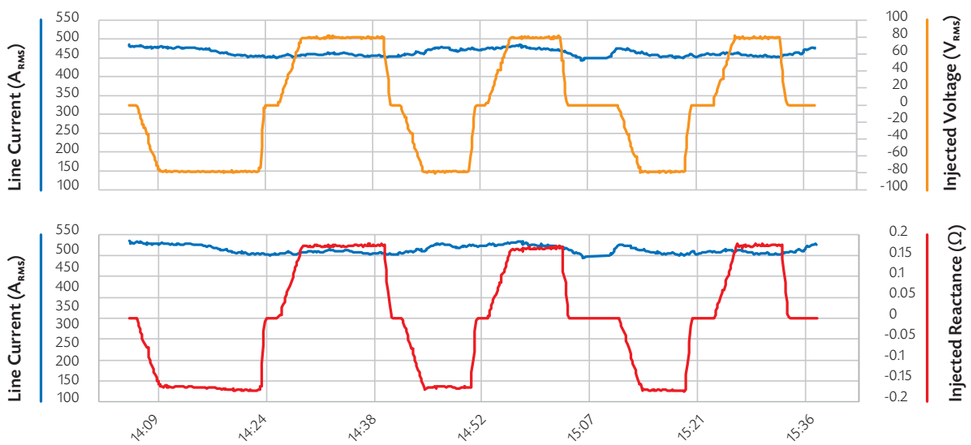
EirGrid conducted power flow studies on the SmartValve units placed on the Cashla-Ennis line during the 2016 pilot. This showed the effects of switching the units from full Capacitive Injection Mode to full Inductive Injection Mode.

This switch was expected to produce a change in reactance of +/-0.07 Ohms, or 0.33% of the Cashla-Ennis line reactance. These values were calculated based on the line operating at its winter continuous current rating of 1149 A.

During the injection test on the live trial, we achieved an increase in expected performance. The SmartValve achieved a change of +/-0.181 Ohms, or 0.83% of the line's reactance.

This was welcome news partially explained by the fact that the line was operating at a current lower than its line rating. These results also show that the SmartValve devices have a high impact on the pulling power of lines operating at a low current. This increases the usefulness and flexibility of those lines.

The red trace in the second graph below show the reactance injected by the SmartValve units (in Ohms). This was measured during a series of injection tests performed in October 2017. It shows the predictable, reliable performance of the units. The equivalent voltage injection (in Volts) of the SmartValve units is shown by the orange trace in the first graph. This shows a maximum injection of approximately +/-80 volts during the injection tests.



Performance for faults

Under fault conditions, the units are designed to enter a bypass mode – in just fractions of a second. This effectively makes them electrically "invisible" to other components of the grid. This includes protection systems such as switches and breakers. The SmartValve units performed as expected during system faults.

Interaction with protection

No changes were required to the existing system protection settings as a result of this project. Over the course of the one year trial there were no unexpected interactions with the normal protection system.

Structural assessment during harsh weather conditions

Following the SmartValve testing in September, Ireland was hit by the tail end of Hurricane Ophelia on Monday 16th October 2017. This caused Met Éireann to issue a Status Red wind warning – the highest threat level possible.

The storm caused significant damage to the nation's buildings and infrastructure. Many roads became impassable and thousands of homes and businesses experienced power cuts which lasted for up to one week. The worst affected areas were in the South and West of Ireland, where the Cashla-Ennis line is located.

Despite strong gusts of up to 156 km an hour on land, there was no structural damage caused to the SmartValve units. Crucially, the units also did not cause any damage to the transmission infrastructure. The three units remained intact and hardly moved despite the gale-force winds of Storm Ophelia. All units remained fully operational through this period.

Going forward – lessons learned

Strategic Lessons

Grid companies are responsible for delivering reliable and efficient electricity. As the pace of change in the energy world increases, organisations like EirGrid need to find new tools to respond quickly to new challenges.

There is an essential need to achieve balance between two key goals. First, grid operators must ensure a stable power supply. But equally, they must also introduce innovative solutions that benefit customers and communities. EirGrid's review of strategy for grid development looked for this balance. The new strategy requires new, yet reliable, technologies to help maximise use of existing grid infrastructure.

SmartValve was identified as a highly promising solution to meet this need. Working together, EirGrid and Smart Wires partnered to prove its capabilities. This partnership approach was one of the key success factors of the trial.

Tactical and detail lessons

During the pilot, one unit briefly lost communication to our servers, which impeded the measurement of its performance. This was discovered to be a software error at the server side and was resolved quickly without a site visit.

After the year of testing we observed some slight corrosion to the plain steel screws on the SmartValve units. Smart Wires changed their exterior fasteners to use a coated stainless steel base material. This provides galvanic compatibility with aluminium, and so eliminates corrosion.

As mentioned above, the circuit on this pilot generally had a low current. This reduced the opportunity for the SmartValve units to deliver operational benefits. This is because the test units were configured to switch on at a minimum current that was often above the typical norms for the test circuit.

Smart Wires are updating this configuration to significantly reduce the minimum current threshold. This will thus provide more opportunities for SmartValve units to deliver their benefits.

Installation Feasibility

Smart Wires has updated the design of the connection equipment so that on-site modifications will not be necessary in the future.

The SmartValve units used in this pilot required a step-down transformer, which adds to the weight of the overall unit.

As a result, we needed two separate machines to install and dismount the SmartValve unit – due to their considerable weight.

In line with our goal to deliver solutions that are mobile and easy to redeploy, Smart Wires has now developed a new SmartValve model without a transformer. This significantly reduces weight, increases mobility and allows for easier installation.

Towards a more secure, yet more flexible grid

The SmartValve pilot can be considered a success for both EirGrid and Smart Wires. For Smart Wires, it was a validation that proved the three units would perform as expected, and without any reliability issues.

For EirGrid, the progressive thinking shown in trialling new technology on a live circuit was rewarded. The trial ran smoothly without causing unexpected issues on the power system – so the technology proved itself capable in practice, not just in theory.

This was the second successful testing of Smart Wires products by EirGrid. In previous years, they carried out Guardian tests at Portlaoise and Cullenagh.

EirGrid is committed to optimising the network to minimise requirements for new infrastructure. As a result of this pilot, EirGrid has confirmed that SmartValve is one technology that has the potential to help EirGrid achieve this goal.

In particular, this technology offers significant flexibility and a rapid solution to emerging needs. This will help EirGrid deliver the commitment to optimise the existing grid to minimise the need for new infrastructure.

This trial demonstrated that the Smart Wires technology allows for installation and operation in a matter of hours.

As a result of the trial's overall success, EirGrid is interested in leveraging this technology. Smart Wires has shown there is potential for considerable benefits in using these solutions throughout the network.

EirGrid and Smart Wires look forward to a continued partnership. These technologies balance innovation and stability in solutions that deliver benefits to the grid, and to the public.

The next step is to consider how Smart Wires can solve real issues on the grid.

Smart Wires
3292 Whipple Road
Union City
California

EirGrid
The Oval,
160 Shelbourne Road,
Dublin D04 FW28