Network Equilibrium – A Simple Project Overview

Project Overview

When a new wind turbine or solar panel farm is built, it has to connect to the electricity network to transport the power generated for homes and businesses to use. Due to the numbers that have been connected in recent years, a range of issues have emerged on the grid meaning in some circumstances there is no capacity to connect or that the connection may be very costly.

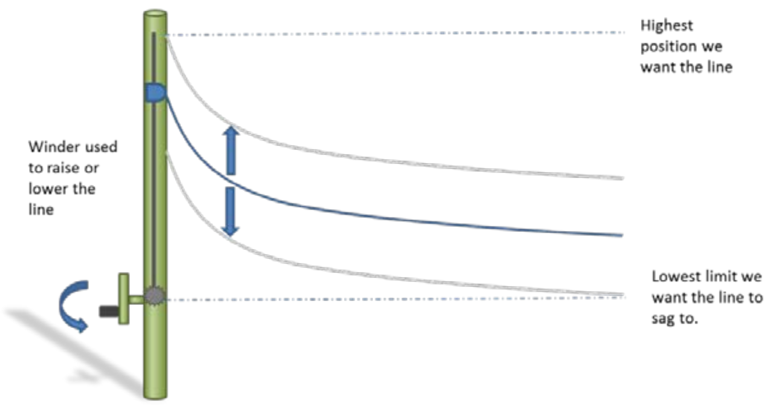
As the network operator, we have to assess and design these connections, primarily with tools not advanced enough to model some of the complex operations we are moving to. Secondly, once wind turbines and other generation are connected it can become more complex to manage the network. In some circumstances this means we cannot connect additional generators without the need for additional expensive network rebuilding. As a result, this can be so costly that projects are stopped.

The Equilibrium project has been designed to address these issues, to improve design and evaluation tools, assess new network operating practices and free up capacity for generators making it easier to connect. This includes the use of System Voltage Optimisation and Flexible Power Links, which are explained in the following pages.

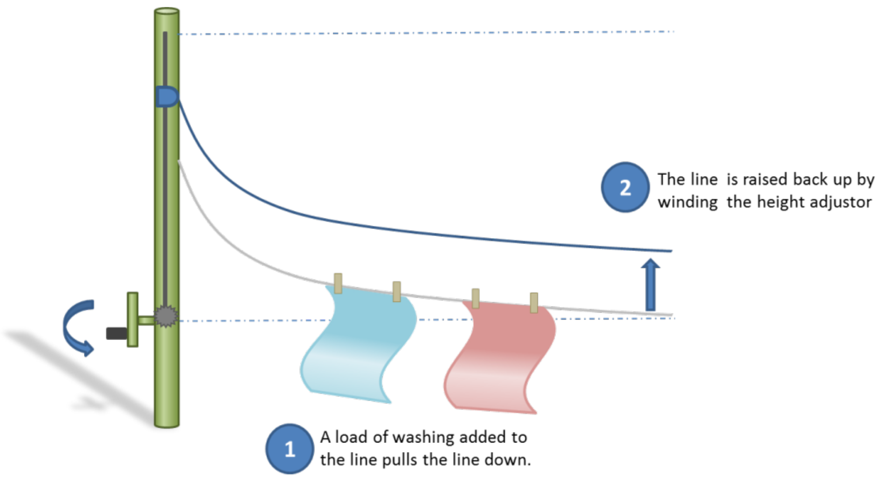
Understanding Network Voltage Control

One of the key issues we face is how to manage the voltage on our network with the presence of generators. If we let the voltage fall too low equipment in homes and businesses may not work properly, get it too high and devices may get damaged.

To help explain why managing voltage with generators is an issue consider the following example. Imagine we have a really long washing line and at one end we have a winder that allows us to raise or lower the line. Ideally we want to keep the line high enough so the washing does not drag on the floor, but not so high that the line can't be reached or it catches in the trees.

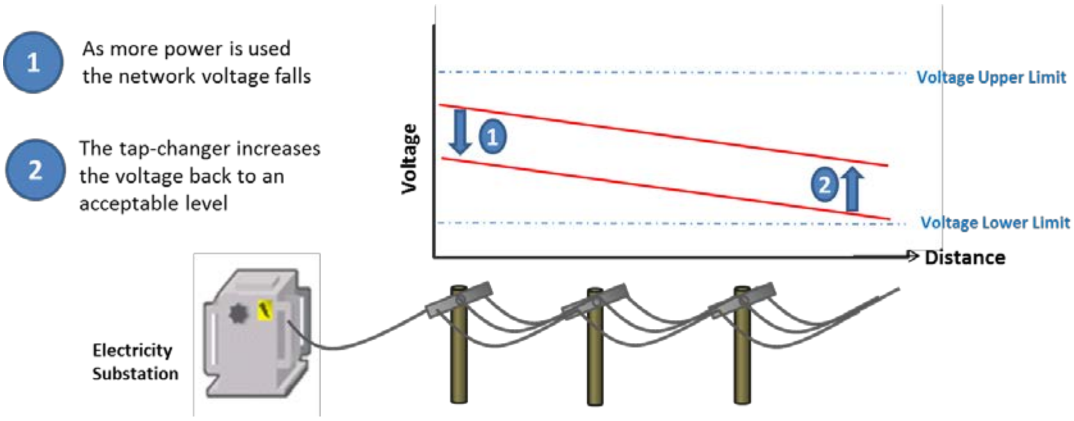


When a load of washing is hung on the line, the weight pulls the line down increasing the risk of the washing dragging on the floor. Winding up at the pole then allows the washing to be lifted.



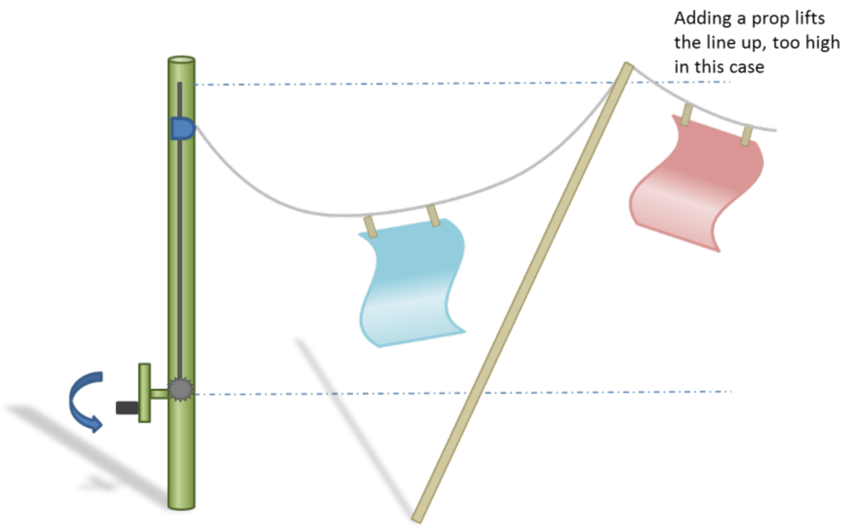
This is similar to how we currently control the voltage on our electricity network.

As electricity flows away from a substation down the cables and conductors, the voltage reduces the further away you get. This voltage falls further as more power is used by homes and business. So, like the winder on the clothes line, we have a device at substations called a tap changer which allows us to turn up or down the voltage to compensate for increasing load and voltage drop on the system. This way we can keep the voltage within the limits we have to work to.



The main challenge with this is to ensure that the voltage across the length of the line is neither too high or too low at all points. So imagine our washing line scenario again. It is relatively easy to control the height of the line if you can see it all. However, our washing line is so long that we can't see the whole length. In fact the only bit we can see is how high the line is at the pole. However based on a number of assumptions such as how stretchy the line is, and how much weight there is on the line we can calculate how much adjustment we need to make to keep the clothes off the floor. This approach is similar to how we model and calculate the settings for our voltage control systems. We can measure the load on the line, and know other factors such as how thick the wires are and how much power they can carry, allowing us to develop static settings for our tap changer controls. Whilst this voltage control technique is automated, it is a fairly passive approach to voltage control as it relies on factors affecting the static settings remaining the same.

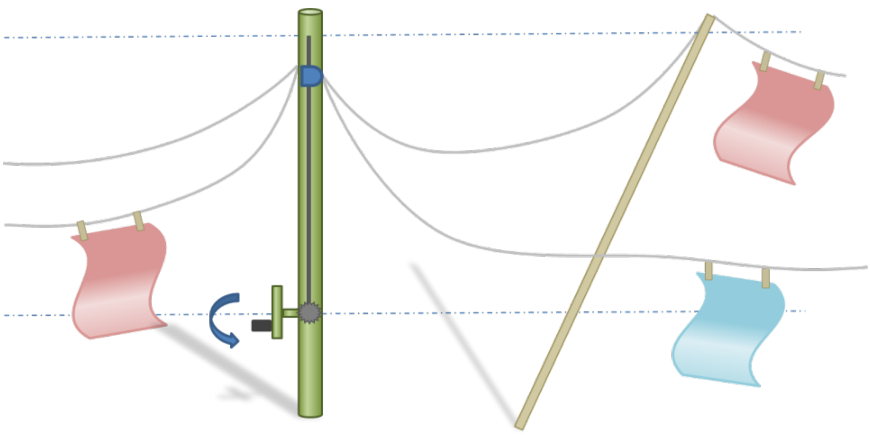
One other aspect we can use to manage the height of our washing line is by adding a prop in the line. This effectively lifts the line and changes its shape as well. However, if we were now to try and model this, the calculations become significantly more complex.



Now imagine the length of this prop can change of its own accord, or even be taken away. Trying to manage the height of the line from the winder alone without full visibility of the line becomes very complex. One solution to this would be to limit the size of the props on the line and cap how many can be used.

This is similar to the effect an embedded generator may have by feeding power into our network. Firstly it can increase the voltage on the network, and secondly it can mask some of the load. In some circumstances, if the load is reduced on the network to a sufficient level, this can result in an excessive rise in the voltage or power flowing back up the network. This can affect the validity of some of the static settings in the voltage control systems making the control less reliable.

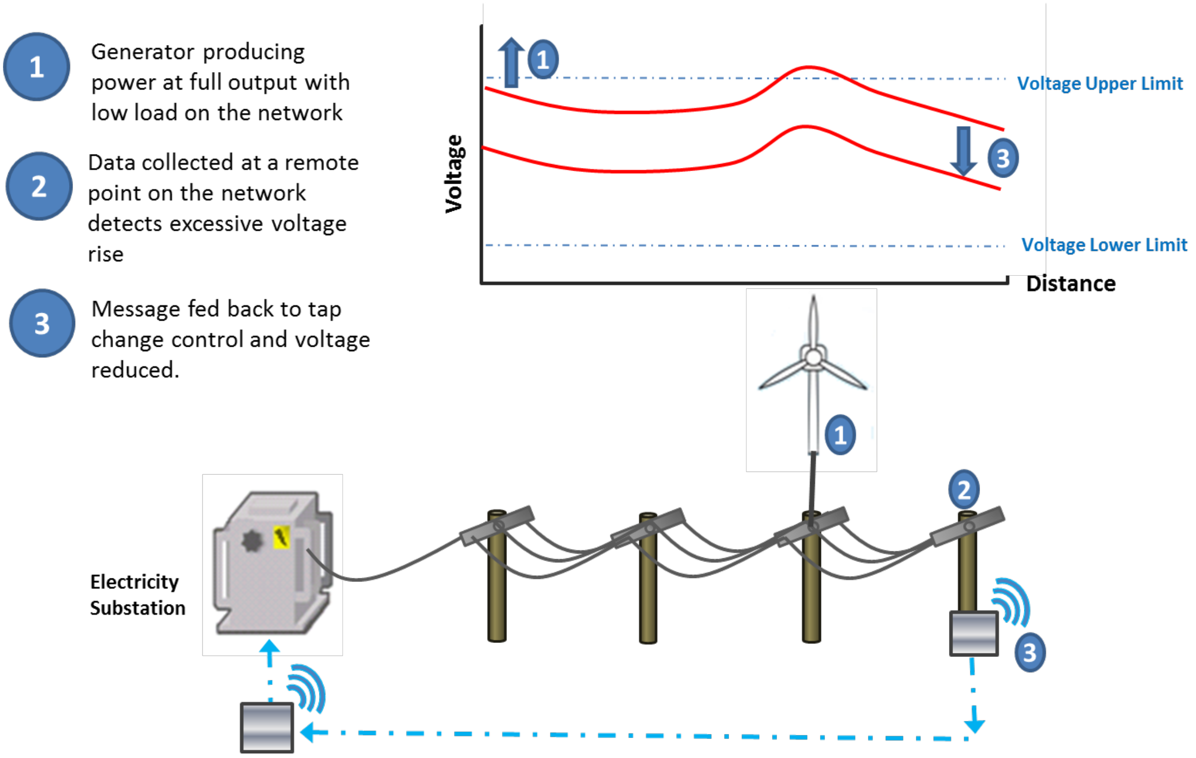
Not only do we have this mix of generation and load to manage, but the generation can be intermittent. As the weather changes, the output of solar or wind generation may vary greatly during short periods. Also, the controls we use to change the voltage does not just affect one bit of network. Going back to the washing line analogy, it is the same as several different washing lines being attached to the same pole with one control.



Therefore, any setting that is made at the pole to adjust the line height has to be appropriate for all the lines attached. Props may be added and removed, as with washing, which makes for a number of complex scenarios.

The solution to this is dynamic washing line control (bear with me on this one). If you can see the full line with props and washing then you can set the height at the pole in the optimum position for all of the lines. If you had someone watching the most critical parts of your washing lines, and reporting back to the pole if the line is too high or too low, you can then optimise the system.

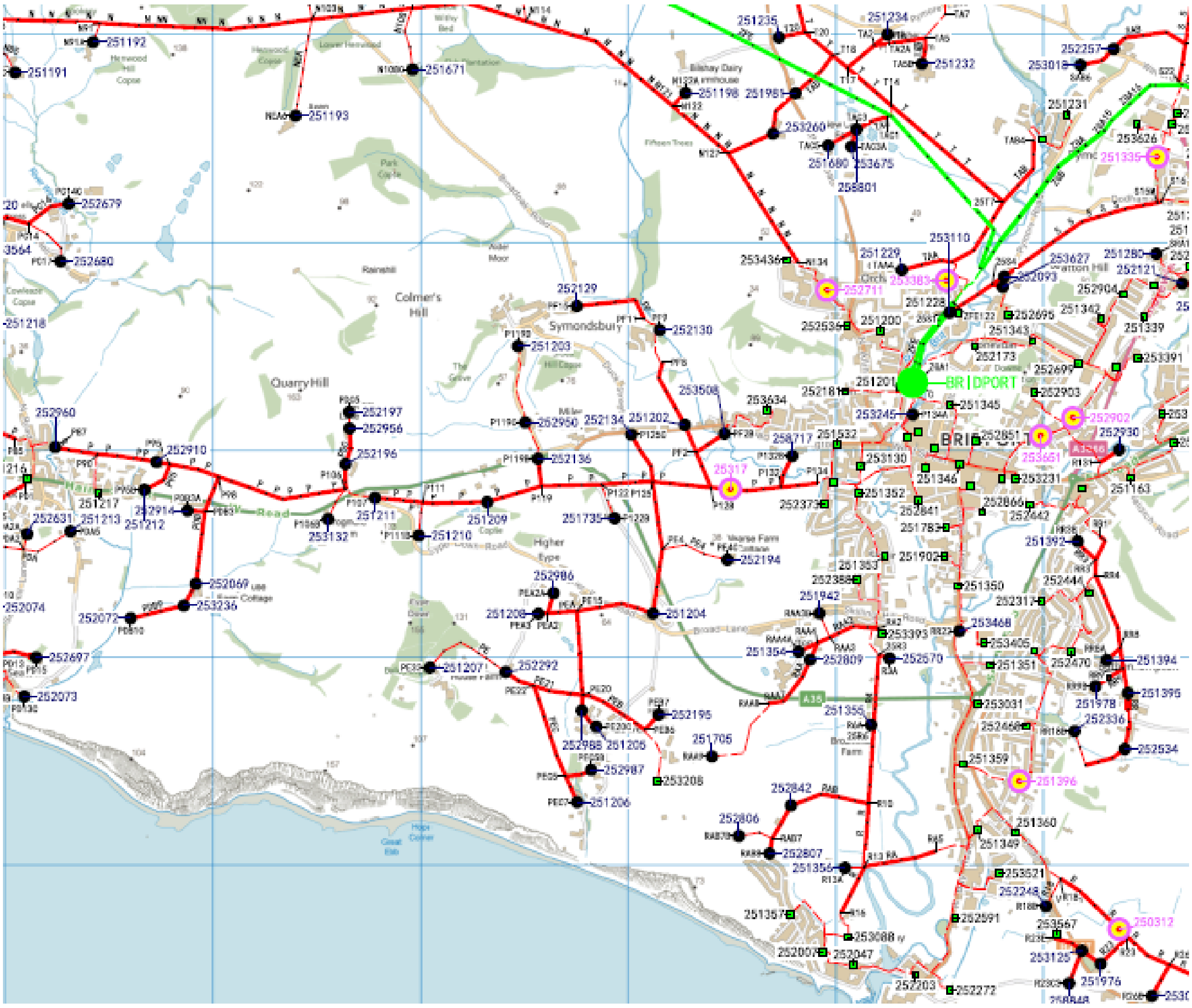
So it is with system voltage control. Information on the voltage across a number of circuits can be collected and then fed back into the voltage control system to allow the optimum voltage to be set for all points of the network.



With Equilibrium, we are looking to deploy system voltage optimisation on a wide scale that will involve covering a network that supplies around 500,000 of our customers. This will create greater security on the network, whilst releasing capacity allowing numerous generators to connect. Additionally, we will develop improved computer modelling tools that will help us understand the complex scenarios on our network before equipment is installed, allowing us to make much more informed decisions, open up capacity on the network and minimise risk to electricity supplies.

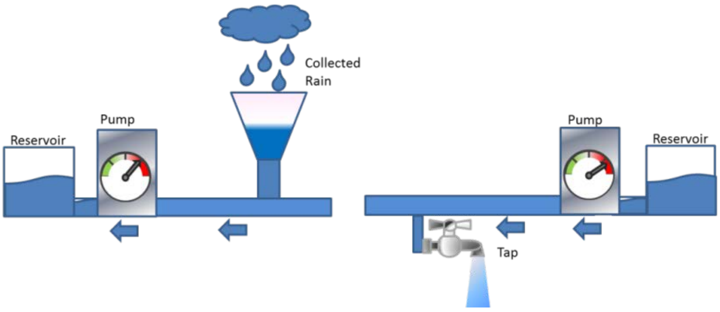
Flexible Power Links

Another area of technology we are going to trial is a Flexible Power Link, a piece of equipment that will allow us to create additional flexibility on how we configure the grid. Our network is made up of many electrical circuits constructed from a mix of underground cables and overhead lines. These circuits run in what is known as a radial design. This can look very similar to trees with sections of line branching off as in the example below. The red lines represent circuits at 11,000 volts, branching out from the main substation, represented by the big green dot.

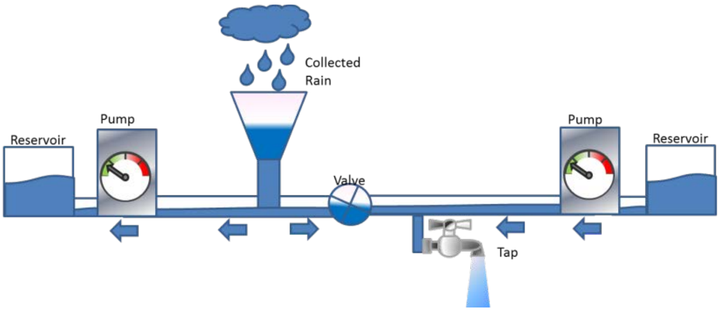


To ensure maximum flexibility in the network, some of the branching circuits connect with other circuits via some form of switch. Usually that switch is off (open) meaning no power can flow between the circuits. However in some circumstances such as faults on the network or maintenance, we may want to join circuits up to change the way power flows. This is done by turning switches on (closed) and connecting the circuits up.

To demonstrate this, and some of the challenges we face, we can consider the flow of electricity to be similar to water flowing in pipes. Imagine two unconnected water pipes. On one side we have a device collecting rain water; on the other side a tap using water. On the rain water side, there is so much water that the pipes are up to capacity and pumps are at full power to move the water away to a reservoir. Meanwhile on the side with the tap, water is being pumped in from another reservoir to meet demand.



As the pipes are at capacity no additional rain water collectors can be added on the left, or taps on the right. To help alleviate these problems a pipe could be added between the two systems allowing water to be used nearer the reservoir, but having no control over this could cause additional problems. The solution is to add a valve that can facilitate this but limit the flow of water between the two pipes. Also, if there is a significant difference in pressure between the two systems, the valve helps to equalise the water pressure.



On some areas of our network, joining two circuits up can have a similar problem. Where two circuits meet the voltage on one side of the switch may be considerably higher than on the other. Closing the switch and joining the circuits can cause some instability in the network and in some causes result in network protection devices turning the power off for safety reasons.

The Flexible Power Link works in the same way as the water valve. It allows us to safely manage and transfer some load between circuits, while also managing any of the voltage difference between the two circuits. Many of the points where this occurs are down to historic network layout arrangements and are now becoming limiting factors in connecting additional generation. Adding the Flexible Power Link technology will allow more capacity to be added for generation by creating additional stability and flexibility on the network.