Introduction to UtonomyOne

2005-000005 Revision A

Technical Details

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Structure of Gas Distribution Networks

Gas is transported from source to consumer via a complex network of pipelines. This gas infrastructure is typically organised into a hierarchy of networks. For example in the UK the gas distribution infrastructure is organised as follows:

The national transmission system (NTS) is a high capacity pipeline connecting the sources of gas (e.g. LNG terminals, international pipelines, gas fields etc) to power stations and eight regional gas distribution networks which are further organised into 13 local distribution zones (LDZ) The national transmission system is designed to move gas over long distances and operates at high pressure. The distribution networks typically operate at lower pressures.

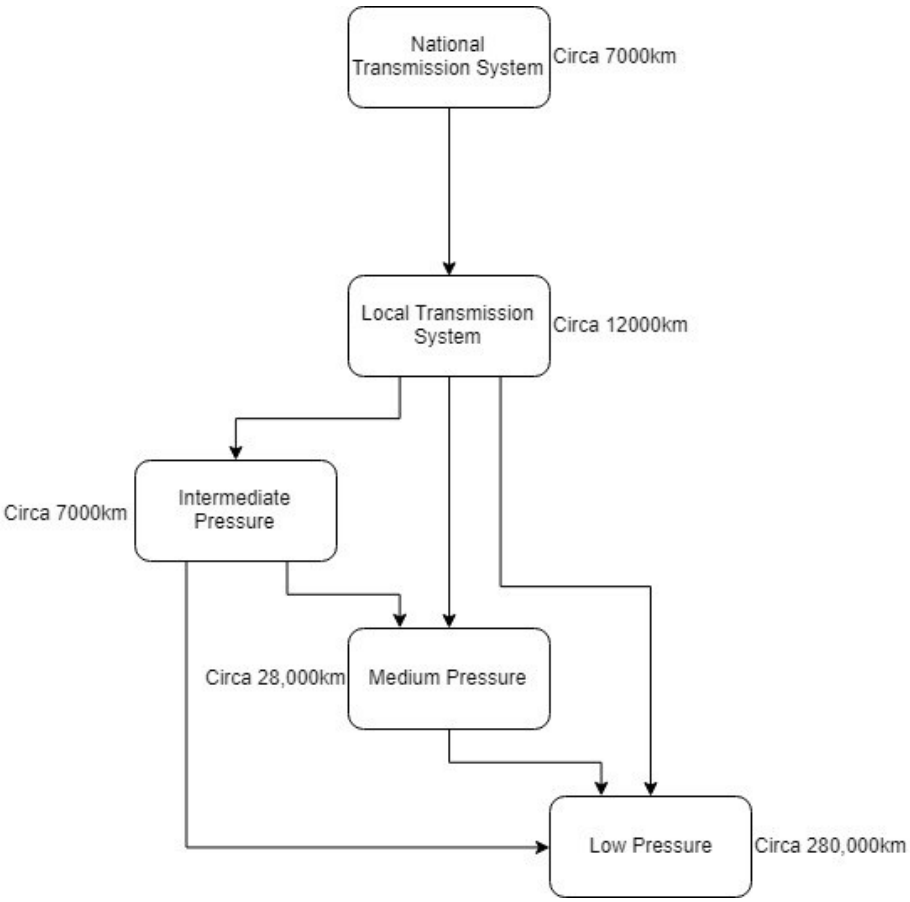

Figure 1 Structure of Gas Distribution Networks

In order to deliver gas to consumers at suitable pressure (e.g. to meet the input pressure specification of a domestic boiler) it is necessary to successively step down the pressure of gas as it traverses the network from high pressure (HP) through intermediate and medium pressure (IP and MP) to low pressure (LP) via a chain of pressure regulation or governor stations. A governor station consists of a set of mechanical equipment that automatically regulate the input pressure of the station to the required lower outlet pressure in accordance with a predetermined set-point. The governor implements a simple feedback control mechanism in order to maintain the desired outlet pressure as demand for gas varies.

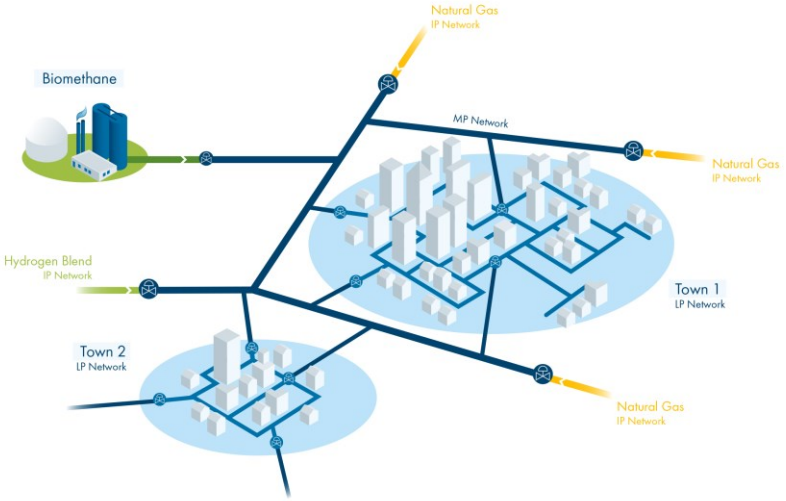

Figure 2 Part of a Gas Distribution Network

The need for Pressure Management

Pressure management is an increasingly important task for gas distribution networks. Leakage is approximately proportional to the pressure in the pipe. Keeping the pressure as low as possible while maintaining minimum service pressures across the network has a significant impact on leakage, helping to keep greenhouse gas emissions to a minimum. Furthermore it is desirable to lower pressure in order to reduce stress on the pipe network thereby reducing the risk and frequency of gas escapes.

Improved pressure management is also becoming essential as gas networks start the switch from natural gas (a fossil fuel) to greener gases such as hydrogen and biomethane. Biomethane is usually injected into the medium pressure tiers of the network. During periods of low demand, the pipeline will likely be pressurised with natural gas leaving no spare capacity to inject biomethane and leading to flaring of the gas at the plant or the plant operating at below its potential capacity. Smart pressure management is required to prioritise the injection of biomethane when it is safe to do so without risking security of supply.

Traditionally, network governors have only been adjusted manually. Changing the output pressure means a technician driving to the site and adjusting the governor. And because most networks have multiple governors, the technician must drive to each of them to change the pressure across the network. This makes the process expensive and ties up valuable resources.

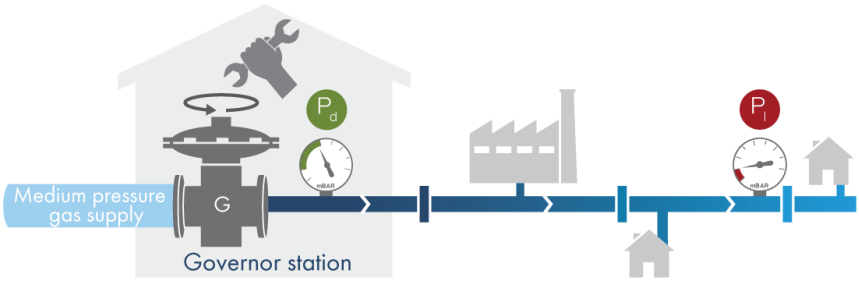

Figure 3 Pressure setpoints

Pressures are set manually at the governor station (P_d). These are usually set at a high level to ensure minimum service levels (P_l) are covered in worst-case scenarios, i.e. the coldest winter day experienced in 20 years.

Demand, however, varies significantly throughout the year and since high demand results in an increased pressure drop between the governor stations and the consumer premises (head loss), governor outlet pressures must be set high enough to cope with those periods of high demand. The choice is either to leave all of the governor output pressures set at the level needed to cope with the worst-case demand, i.e. a 1-in-20 winter, or make seasonal adjustments by hand. With the former, the pressure ends up being too high for 99% of the year, with the latter, scarce resources are tied up. Seasonal adjustment also involves tricky judgements about the weather; governors set to spring settings in March for example would need to be adjusted back to winter settings at considerable cost in the event of an unexpected cold snap in April.

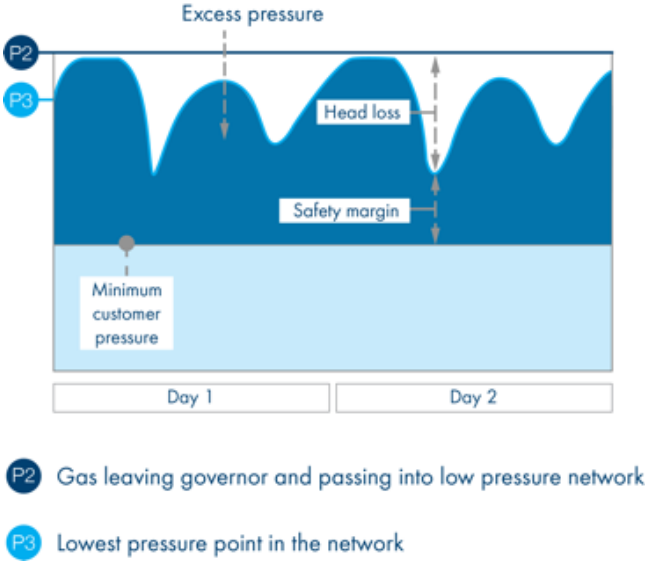

Figure 4 Demand and Excess Pressure

Demand massively varies throughout the year. On a cold winter morning, it may be many times more than on a summer evening.

Pressure Management with UtonomyOne

Utonomy's patented technology actively manages the pressure in gas distribution networks to reduce leakage of environmentally harmful methane, while providing critical network data. Looking forward, its

products will facilitate the injection of hydrogen and biomethane into the gas network, which is key to the transition to a net zero gas network.

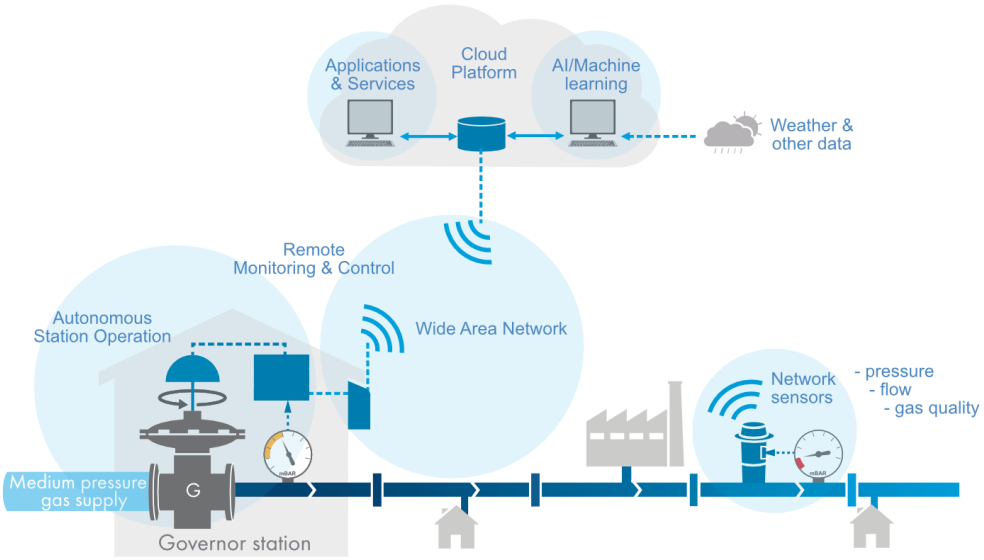

Figure 5 Utonomy's vision of a Smart Gas Network

The solution from Utonomy eliminates the need for governors to be manually adjusted, resulting in lower operating costs and enabling pressures to be adjusted much more frequently. Utonomy's pressure control solution enables the governors to be automatically adjusted so that the pressure in the network matches demand. This leads to lower average pressures in the network and as the leakage is proportional to the pressure, leakage is significantly reduced. The Utonomy solution consists of patented hardware combined with innovative software.

Utonomy's locally installed hardware communicates via wireless networks with Utonomy's cloud platform. This stores network data and hosts the remote-control software which enables monitoring of the gas pressure throughout the day and the download of updated pressure schedules as necessary. The network data can also be used to pinpoint irregularities in the network. For example, currently if a customer is experiencing low gas pressures, an engineer is unable to tell which governor requires adjusting and hence needs to visit all the governors feeding the network (in a town such as Winchester, there may be 20 governors feeding the network). Utonomy's software enables the correct governor to be quickly and remotely adjusted to solve the problem.

Easily retrofitted to existing governors in a matter of hours, operators can then update the pressure schedules applied to their networks either from their desktop or connected device such as a smart phone or tablet.

Future developments will employ advanced machine learning to automatically optimise setpoint schedules to account for predicted demand on a daily basis.

Overview of the UtonomyOne solution

The UtonomyOne product family

UtonomyOne offers a modular, extensible solution for pressure management in gas distribution networks, built around the Ucontrol pressure control equipment which enables local autonomous operation of the governor station, Uconnect which adds wireless connectivity for telemetry and remote control and Ucloud, the central platform for managing the remote equipment, storing and processing data and hosting a range of software applications and services.

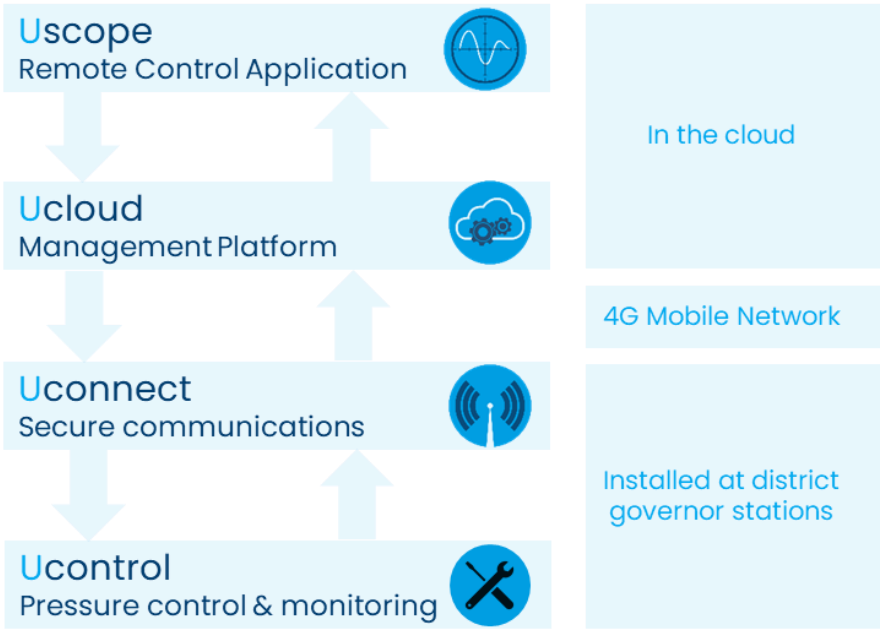

Figure 6 The UtonomyOne product family

Controlling pressure with Ucontrol

In a typical Ucontrol installation an electro-mechanical actuator is fitted to the pilot valve of the governor to be controlled, effectively replacing the manual adjustment screw and acting via a control spring on the diaphragm of the pilot valve. By extending or retracting the actuator by an appropriate amount the controller is able to adjust the setpoint of the pilot valve and hence indirectly, the setpoint of the main governor.

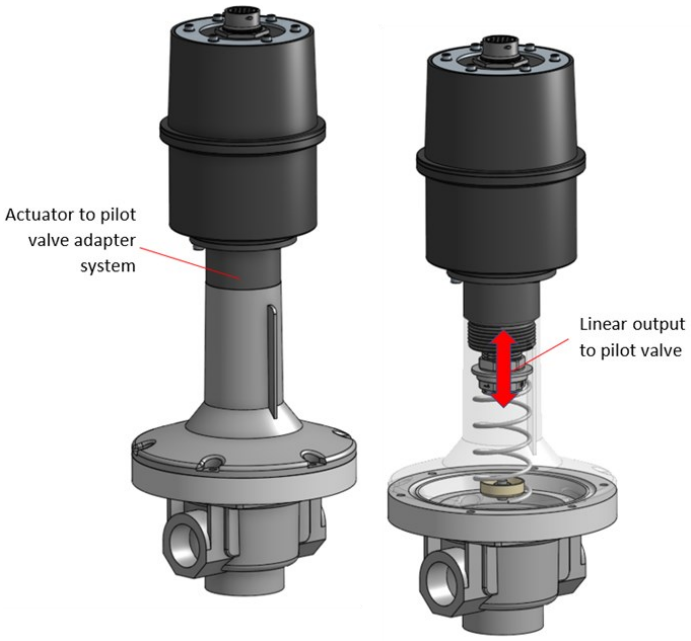

Figure 7 Linear actuator acting on Pilot Valve diaphragm via control spring

In order to maximise battery life and to avoid oscillations and instabilities that would arise from close loop control, Ucontrol employs a mathematical model to determine the correct actuator position for a given outlet pressure setpoint. This model is configured during system commissioning.

A range of mechanical adaptors allows the actuator to be fitted to different models of pilot valve.

Setpoint scheduling

In the simplest entry level configuration, Ucontrol equipment is installed at each governor station in the network and locally configured with a schedule of pressure setpoints by the field engineer. Following successful commissioning, Ucontrol will operate autonomously and without further interaction to adjust the station's outlet pressure setpoint in accordance with the configured schedule. No remote connection to the cloud is required to support this basic standalone solution.

The "setpoint schedule", is a list of desired outlet pressures each associated with a specific start date and time.

At the specified time the controller will select the appropriate pressure and convert this into a target actuator position using the model described above. The actuator will then be extended or retracted as necessary to achieve the target position and desired governor setpoint. Once the target position has been reached the actuator will hold this position until the next scheduled setpoint.

In a typical deployment the setpoint schedule might be configured with 4 setpoints that repeat each day during a season, supporting pressure increases to cope with morning and afternoon peaks in demand with reduced pressures overnight and during the middle of the day when demand is lower. By configuring 4 sets of 4 setpoints each of the 4 seasons can be programmed in a single visit.

Figure 8 Setpoint Schedule in the Utonomy Field Tool Application

Figure 9 Pressure data showing daily setpoint scheduling in a small network

Twin stream control

Ucontrol has been designed to be deployed in both single and twin stream governor stations. In the twin stream configuration, the working and standby governors are each fitted with an actuator under the control of a single controller which synchronises the setpoint adjustment for each stream.

During commissioning of a twin stream governor station, the field engineer will configure the controller with the appropriate pressure offset between the streams. During operation the controller automatically subtracts this offset from the scheduled setpoints in order to determine the correct setting for the standby stream. At the scheduled time of day the controller will adjust the setpoint of each stream in sequence, the order being dependant on the direction of the setpoint change in order to avoid reducing the separation between the streams which otherwise might trigger oscillations in the system.

Safety & Security of Supply Protection

Ucontrol is designed to retrofit to unmodified[1] pilot valves and employs the standard adjustment mechanism to change the setpoint. There is no interference or interaction with typical safety devices (e.g. slam shut valves, monitor regulators etc) which should continue to be fitted to provide the necessary level of protection as determined by the gas distribution network (GDN).

Ucontrol incorporates a number of features to improve reliability, fault tolerance and security of supply. These include:

Mechanical Range Limiter: Utonomy actuators incorporate mechanical range limiters which prevent the actuator from moving outside a safe operating range due to electrical faults, software issues or accidental or malicious operation. This effectively locks the minimum and maximum setpoint that can be set by the system. The positions of the mechanical range limiter are set during commissioning.

Built in Test: The controller performs a comprehensive built in test of critical components and interfaces every day and continuously during certain key operations. Critical failures result in governor setpoints being raised to a preconfigured "safe high pressure" in order to ensure security of supply.

Low Pressure Trip: The controller continuously monitors the outlet pressure of the station and compares this against a preconfigured minimum level. If the pressure drops below the threshold then this is treated as a critical error condition and the governor setpoint will be raised to the "safe pressure" setting.

Temperature Boost: Ucontrol can be configured with a low temperature threshold and an associated pressure boost. If the ambient temperature measured by the controller drops below the configured threshold then the governor setpoints will be increased by the boost amount.

Remote Pressure Management

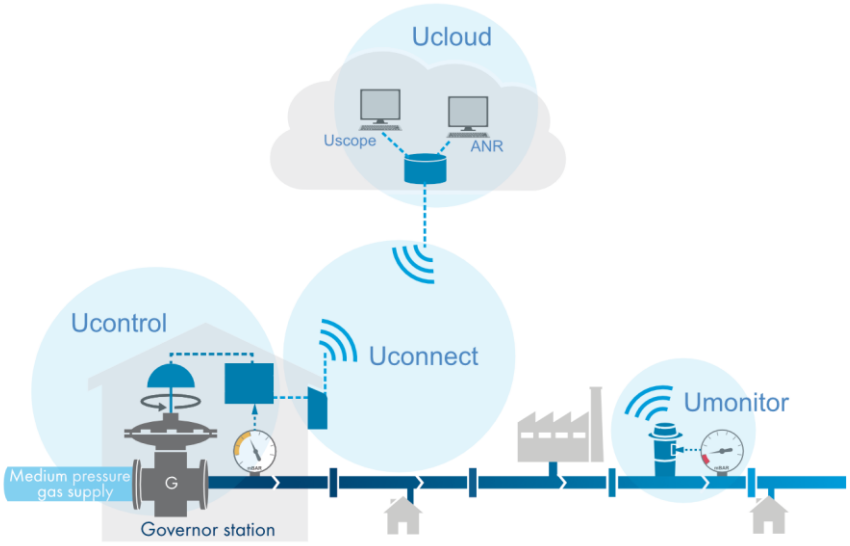

Figure 10 UtonomyOne Remote Pressure Management

[1] It may be necessary to replace the standard pilot valve spring with a custom spring supplied by Utonomy in order to obtain the desired range of control. Certain specialised governors may require additional equipment and/or modification in order to be integrated with Ucontrol. Refer to the relevant application note.

With the addition of Uconnect, Utonomy's remote control and telemetry sub-system, and Ucloud, Utonomy's device and data management platform, the governor stations can be connected to advanced software applications such as Uscope and to users based in regional offices, central operations centres or on the road.

Uconnect provides secure encrypted communications between the station equipment and Ucloud over LTE cellular networks. As an added security measure all communications are initiated from the remote station and Uconnect incorporates a firewall to block all attempts at inbound communication.

Most governor sites in low pressure networks are not connected to the electricity grid so Uconnect is powered from a solar panel with a buffer battery to supply power overnight and during extended periods with reduced sunlight. In order to preserve power, Uconnect spends most of the time in a low power state, waking up at preconfigured intervals to collect and log data from Ucontrol and to synchronise with Ucloud.

Ucloud is Utonomy's device and data management platform providing generic services to connect and manage remote devices, ingest data, route commands and operations to devices as well as operational storage, user management, reporting, visualisation and system administration. Ucloud also hosts Utonomy's growing range of user facing applications (e.g. Uscope) and automation services. Ucloud and its associated applications are available as a Software as a Service (SaaS) deployment model.

The Uscope application provides users with a series of management dashboards enabling them to understand at a glance the health and status of the connected pressure management sites across the whole network with the ability to drill down into detailed information for individual stations. Users are able to monitor alarms forwarded from the remote sites and view detailed graphs of network pressures including near live and historical information, directly in the application or offline using exported data and reports. Crucially, authorised users can edit setpoint schedules to reflect latest seasonal settings, react to anomalous weather events or perform further optimisation of network pressures. Updated schedules are then queued in the cloud for automatic upload the next time the target governor station is online.

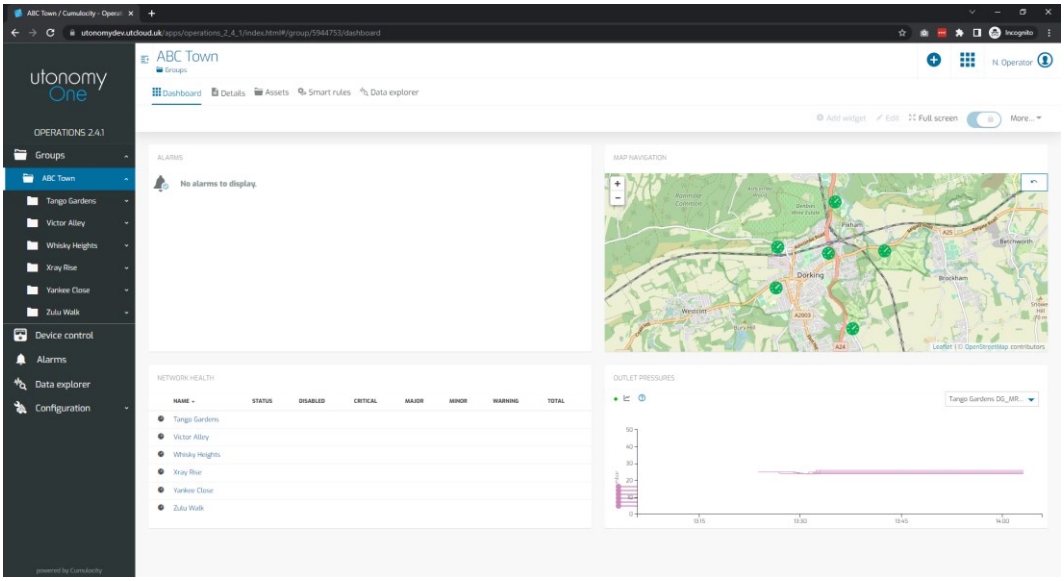

Figure 11 Network level dashboard in Uscope

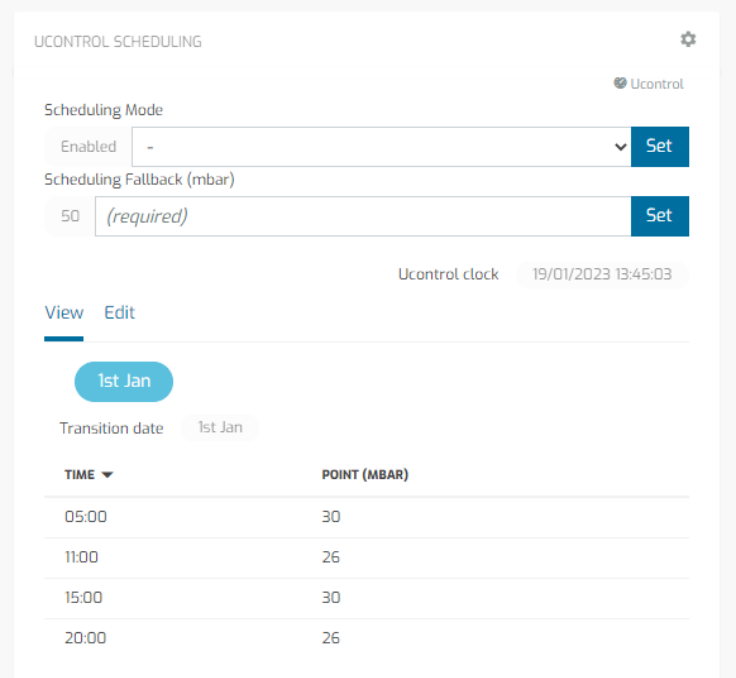

Figure 12 Uscope Setpoint Scheduling widget

Under Development

Umonitor provides the means for GDNs to extend the instrumentation of the network beyond the governor station. By deploying Umonitor equipment at network extremities, pressure monitoring of the whole network becomes possible with data collected and presented through the same Uscope application or made available to other software applications in the Ucloud environment. If required Umonitor can be configured to trigger alarms when specified pressure thresholds are crossed and these can be relayed to users through the Uscope dashboards and optionally via email or SMS.

Utonomy's Automatic Network Response (ANR) service can be configured such that a Umonitor alarm automatically triggers a command to increase the pressure at one or more governor stations.

Upredict is a machine learning/AI extension to UtonomyOne which after learning the characteristics of a network and the relationship of demand to weather conditions is able to automatically generate setpoint schedules which are optimised to meet predicted demand.

Beta releases of Umonitor and ANR are planned for summer 2023. Upredict is expected to enter live field trials in early in 2024.

Revision History

Revision	Date	Summary of Changes
A	01/02/2023	Initial release