VIRGINIA TECH:

Bridging the OT-IT Divide

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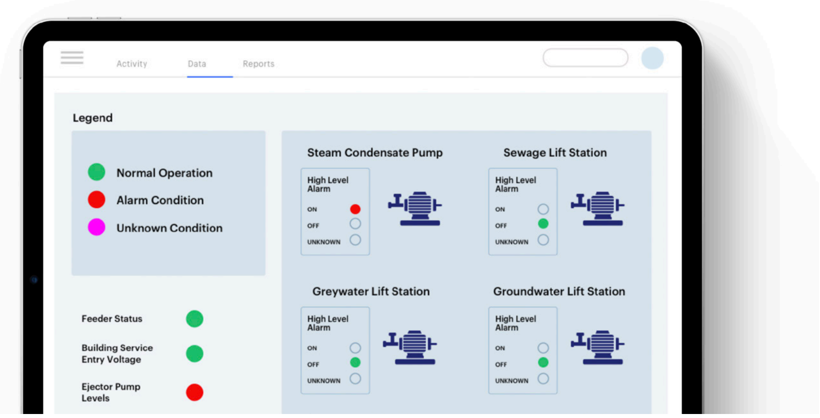
Report Introduction

Virginia Tech is committed to promoting and implementing long-term sustainability best practices in support of an improved physical and academic environment for students, faculty, staff, and society.

Unlike many other Universities that provide services solely to their main campus, VTES delivers electricity to the Blacksburg campus, Corporate Research Center, and to approximately 6,000 residential and commercial electric customers. Therefore, VTES must be able to meet the dynamic needs of the University and the local community. Whether it is powering Lane Stadium with electricity on game day for 65,000 fans or maintaining almost 4,000 street and sidewalk lights across campus and Blacksburg, VTES has a goal to deliver improved energy efficiency, resiliency, and top-notch service.

As part of VT's Climate Action Commitment, the following goals have been set. ⟶



Carbon Neutral Virginia Tech Campus by 2030

100% Renewable Electricity by 2030

- 2027 Develop battery storage 10 MW on campus
- 2029 Purchase solar 100 MW in region

Total conversion of steam plant fuel to natural gas by 2025

- Plan for a full transition to renewable steam plant fuel after 2025

Reduce Building Energy Consumption to Enable Carbon Neutrality by 2030

- 2021 Green Lab Certification program launched campus-wide
- 2030 Energy management reduces energy intensity by 20% below 2020 baseline

Operations of new buildings initiated after 2030 will be Carbon Neutral

- 2026 Develop plan for showcase zero-net-energy building on campus
- 2028 New building energy intensity 40% lower than 2020 existing buildings

Background

The primary Utilities locations for the Virginia Tech campus are: 601 Energy Drive and the Central Steam Plant located between Old Turner Street and Barger Street. The Central Steam Plant generates an annual steam output greater than 943 billion British Thermal Units (BTUs) and provides campus buildings with a portion of their heat, hot water, and electricity needs.

In addition to the central Steam Plant, VT is in process of renovating their chilled water infrastructure with the installation of three state-of-the-art 3,000-ton chillers (two in the North Chiller Plant located on Stanger Street, and one in the Southwest Chiller Plant located in the Duckpond Drive Parking Lot. These new chillers are part of a plan to create one continuous chilled water loop with four miles of new underground piping across campus to connect the North and Southwest Chiller Plants, along with stand-alone chiller systems installed in buildings on campus.

The result of this chilled water system integration project will present an opportunity to holistically optimize the distribution and management of chilled water. To successfully optimize the generation and distribution of utilities across a multi-building environment like VT, it is necessary to aggregate data from operational technology platforms that traditionally operate in silos.

Control platforms are not designed to store large quantities of data; they are control platforms. As control system vendors and end-users begin to realize the value of information that exists in their data, control systems are being pushed to perform as historians and analytics packages, with varying levels of success. Physically storing data on control systems (i.e. on control panels or at the system's head-end server) will eventually impact the functional performance of the system.

In fact, most control platforms store data in relational databases (like SQL) instead of purpose built time-series databases which are far more effective at storing huge quantities of data. Furthermore, broadening the level of access to control systems beyond operators creates additional operational risk. This risk ranges in severity from juggling license 'seats' to un-, or under-trained personnel accidentally modifying or deleting parts of the system.

The data aggregation process is further complicated by the security-first network architectures that 'air-gap' critical control systems – those tasked with utility generation and distribution – from enterprise information technology environments. This concept of connecting OT and IT systems is commonly referred to as the OT-IT convergence.

Bridging the OT-IT Divide

The best place to start a conversation on the convergence of Operational Technology (OT) and Information Technology (IT) is with a refresher of the Purdue Enterprise Reference Architecture (PERA), also known as the Purdue Model. The Purdue model – first described in the 1990's by researchers at Purdue University – describes a tiered architecture that comprises OT and IT devices. It's purpose is to define best practices for the relationships that should – and should not – exist between the different tiers of a **six-level hierarchy**.

Level 5
Enterprise Networks. Internet Access

Level 4
Local Business Networks. Intranets

Level 3
Supervisory Control & Data Acquisition (SCADA)/Historian Servers

Level 2
Human Machine Interfaces (HMI)/Digital Control Systems (DCS)

Level 1
Logic Device. PLCs, BAS controllers, etc.,

Level 0
instrumentation. Sensors, actuators, IoT Devices etc.,

LEVELS 0 THROUGH 3 represent the OT ecosphere with levels 4 and 5 the IT ecosphere. OT and IT environments have discrete goals and objectives: OT networks are designed to monitor and control physical operations whereas IT networks are business-focused and designed for communication and resource sharing. It is very important to avoid direct connections from OT devices and systems to servers that live in the IT domain.

Since the earliest ages of industrial control, dating back to the 1960's when the Modicon 084 was developed by Bedford Associates group, Operational Technology (OT) platforms have operated on dedicated control networks. Many OT devices will perform their given function for well over 20 years; they are designed for resilience, designed to last. Part of their resiliency results from the simplicity of their design. Most controllers do not run on standard Operating Systems and they are rarely patched to update functionality and/or cybersecurity vulnerabilities.

This hasn't presented a major cybersecurity vulnerability in the past because OT networks relied on network segmentation and architectural defenses for security. This statement was true at Virginia Tech where the Virginia Tech Electric Service and Virgina Tech Power Plant networks were isolated, by design, with limited or no remote access capabilities.

INFORMATION TECHNOLOGY (IT) NETWORKS – where business systems sit – have been physically separated (i.e. using different physical media to transfer data) from their OT counterparts. The logic behind this is simple. Industrial controllers, like PLCs and typical Building Automation System (BAS) control panels, are designed to perform specific tasks for a prolonged period. This is drastically different than the IT servers that are often at end-of-life within 5 years and require constant cybersecurity management.

Over the last 5 years, there are 4 major drivers towards extracting operational data from the OT environment:

1

Campus level energy optimization

The future of campus energy operations will rely on data-driven decision making. This will apply from the source of power (optimized dispatch, for example), grid-interactivity (supplying and drawing power to and from the commercial utility grid, as needed), demand side optimization (through FDD and other initiatives), and evolving maintenance practices (e.g. CBM). The combination of these initiatives will result in more resilient utility distributions systems that minimize unscheduled downtime. Additionally, analyzing operational data is critical to capacity planning in support of campus expansions. Each of these initiatives rely on a holistic understanding of how existing energy demands are met across a campus. This can only be achieved through the aggregation of standalone operational data sources into a central location.

2

Environmental, Social, and Governance Goals:

Universities like VT are committed to improving the learning environment for students and reducing the environmental impact of their operations. VT's CAC mandates a transition toward carbon neutrality with support from on-site renewable energy and a reliance on cleaner fuels. VT's progress towards these goals can only be monitored by evaluating operational data. Similarly, optimizing the learning environment and improving indoor air quality for students requires continuous monitoring of operational data.

3

COVID-19 and Remote Work:

The COVID-19 pandemic has forever changed the traditional working environment where most employees worked on-site, full time. While most critical functions (e.g. power plant operators) still work on-site around the clock, many of the supporting functions (e.g. data science, energy management, sustainability) now work from home, for at least part of their working week. Many of these stakeholders require OT data so getting OT data into a secure, remotely accessible location is a necessity.

4

Machine Learning and Artificial Intelligence:

Traditional OT platforms do not possess the computational power required to perform advanced analytics. Even if they did, it is not advisable to perform analytics on a server that is tasked with physical control, like a DCS. The separation of functions is an important key to improving overall reliability. For these reasons, extracting data from the OT environment and bringing it to an enterprise tier, and even the cloud, is important to unlock the value that exists within your OT data.

Digital Transformation at Virginia Tech

The two most important components of VT's Operational Digital Transformation were:

Cybersecurity

In total, VT 'connected' three separate networks to create the Operational Data Warehouse (ODW). The networks were associated with the Power Plant, the Electric Service, and the VT Enterprise. To retain the air-gaps that existed between these critical OT networks and VT's enterprise IT network, data diodes were deployed at the Power Plant and the Electric Service. Utilizing data diodes maintains the physical separation between critical and less critical networks while allowing unidirectional data flow. VT's utility metering infrastructure and building automation systems are hosted on VT's enterprise network.

DATA SOURCES

- Wonderware SCADA
- Ignition SCADA
- Siemens Building Automation System
- RedLion Metering Panels

Structured Data Aggregation

The networking and cybersecurity configuration changes that are required to enable data aggregation from various OT platforms are important first steps in the process of digital transformation. Once a platform has been deployed and data can securely flow from each source system to the operational data warehouse, the data design and data management processes begin. The data design process requires considered thought of the desired outcomes from the ODW. For VT, there were a number of important applications that drove the deployment of the ODW; these included energy monitoring for the Office of Energy Management (OEM), outage management for the Electric Service, geospatial visualizations of utility distribution, and a remotely accessible replication of the power plant SCADA.

These desired outcomes are an important part of the data design process and support decisions on the frequency of data transmission, asset hierarchies, analyses, notification types, and visualizations. Leveraging industry best practices in the area of interoperability is also critical so the data stored in the ODW can interface with other platforms (ML/AI software, maintenance management, inventory management, etc.,). The most important initiatives in this space currently are Project Haystack, Brick Schema, and the soon-to-be-released ASHRAE 223 standard which aims to provide a unified data semantic modeling solution. Incorporating guidance from this standard will address many of the challenges that have been introduced over more than 20 years of inconsistency between vendors, control technicians, and other stakeholders around naming conventions, engineering units, and other parameters.

Without this centralized data set, stakeholders are required to interface with a variety of platforms to download data (if the data points in question have been setup to trend and record) before compiling the data in another platform (typically MS Excel or Python). This is a time consuming and tedious process that is eliminated with a secure data aggregation platform like the ODW at VT.

Data-Driven Applications @ VT

Electrical Outage Management

One key component of the VTES mission is reducing the response time to electrical outages within the area of service. Improving the resolution of data and eventually getting to a building-level understanding of the status of power is the end goal.

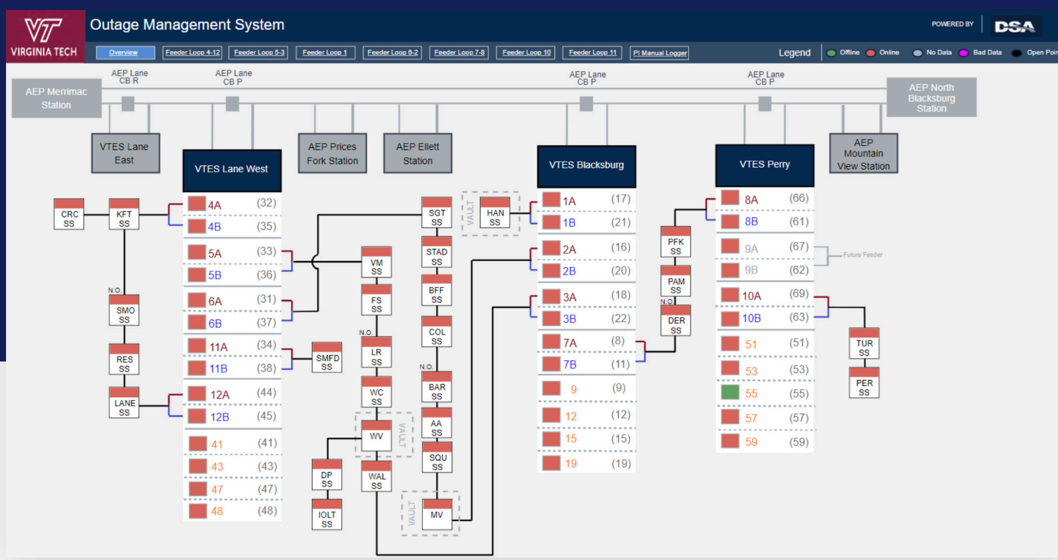


Figure 1. Virgina Tech Outage Management System – Overview

There are various planned initiatives (e.g. upgrading electrical switching assets and advanced metering infrastructure installs) that aim to increase the level of insight available to VTES operators in real-time. All of these data sources will be incorporated into the ODW as they become available but the initial VT goal for the ODW project was a basic outage management system (OMS) that would evolve over time. The initial OMS application within the ODW utilizes readily available feeder breaker "status" signals collected from the VTES SCADA and associates these status points with building and transformer inventories associated with each feeder.

The main feeders are supplied from each of the four campus substations in service. The approach took advantage of the high availability and resilience of the existing WW network and provided a functional alert that would return all impacted buildings when any feeder breaker opens. A visualization of one part of the outage management system is included here: This is the first iteration of the data-driven outage management system at VT and there are limitations with the existing approach due to the lack of building-level insights currently available.

To address this limitation, VT is exploring new data sources that can directly monitor the status of power (e.g. smart ATS) or can infer the status of power by proxy (e.g. fire alarm system). The deployment of this initial outage management system also supports infrastructure upgrade investment decisions. A complete characterization of the devices responsible for transmitting power across VT has identified the specific pieces of equipment that require upgrade; this is another valuable outcome of a move towards data-driven operations.

Utility Distribution Visualization

The ability to visualize the generation, distribution, and consumption of energy across the VT campus in real-time, in a single application is extremely valuable. From an operational perspective, visualizing common issues (e.g. low differential temperatures and pressures in a chilled water loop) in a geospatial context simplifies troubleshooting and remediation efforts. The application of targeted analytics with supporting alerts and notifications assists district plant operators by providing advanced warning of issues impacting efficiency and/or performance. These analytics include traditional fault detection rules (e.g. clogged cooling tower strainers, operator overrides) in addition to more advanced analytics that provide optimized dispatch recommendations to plant operators. These machine learning algorithms require a range of inputs (e.g. weather forecasts, utility rates, occupancy profiles, others) to present the optimal combination of assets to meet the current and forecasted load. Leveraging tools like the ODW at VT improves the productivity of operations and maintenance groups as their work is now supported by continuous analytics that help prioritize tasks.

The geospatial interface is also a powerful tool that can be used after an outage occurs. With the 'playback' feature available within ESRI's ArcGIS platform, it is possible to watch the combination of events that led to a service disruption with the goal of identifying improvement opportunities that avoid recurring issues. From the perspective of capacity planning related to campus expansions, the ability to visualize changing consumption patterns across a campus provides unique insights. While engineering design documents provide some detail on available capacities, the day-to-day running of a campus rarely aligns with design documents. For this reason, having access to trended data from the assets that generate, distribute, and consume utilities provide actionable insights that support investment decisions (e.g. retrofit vs replace) and operational/maintenance decisions. The image below shows a geospatial interface with real-time steam consumption information for the VT Blacksburg campus.

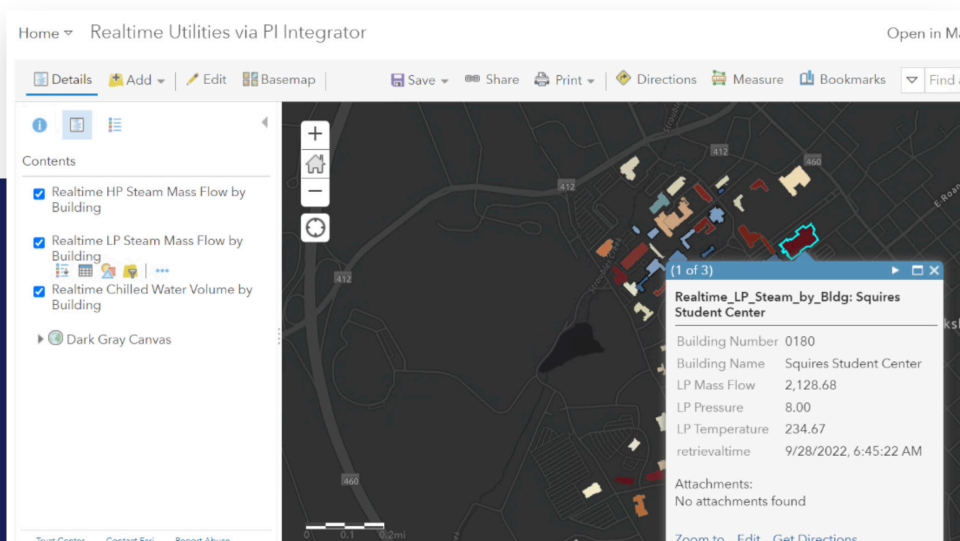


Figure 2. Virgina Tech GIS Utility Map – Steam

Conclusion

Campuses all over the world are considering how their critical infrastructure fits in with their overall sustainability initiatives. At the forefront of these campuses is Virginia Tech.

Virginia Tech has big, far-reaching goals to reduce their environmental impact across their campus, and to reach these goals, they need an ambitious plan and an experienced team to execute that vision. At Virginia Tech, sustainability and environmental impact are top-of-line issues, and they are using this opportunity to change their philosophy on how they plan, design, implement, and, most importantly, continuously optimize their critical infrastructure. Shared data, systems integration, and analytics power this approach, and this data-first philosophy enables campuses to realize efficiency and value in their systems like never before.

THE EFFECTS OF THIS TRANSFORMATION ARE PROFOUND

More resilient systems with less downtime, better energy demand optimization, a reduced environmental impact, and cost reduction across Virginia Tech's energy infrastructure.

Bridging the OT-IT Divide

By bridging the OT-IT divide, Virginia Tech's isolated, siloed systems will be replaced by a sophisticated analytical powerhouse of connected systems that will serve them and their constituents well for many years to come.