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Revision 0

Modifications to the Thermal Energy Distribution System (TEDS)

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SUMMARY

Operations with the Thermal Energy Distribution System (TEDS) began in August 2021. During shakedown testing, a system perturbation caused a discharge of hot heat transfer oil from a high-point vent. That oil splashed onto hot piping and filled the lab with oil vapor. The resulting incident investigation revealed shortcomings with the TEDS system design, namely that there was no flame detection system installed. In addition, the ensuing incident investigation revealed that switching to a slightly more industrial-style control system would enable long-term research goals—unattended operation, integration with a digital twin, and integrated system operations.

Idaho National Laboratory (INL) awarded contracts to design and install a new control system based on Opto 22 hardware, an edge-network controller, and Ignition software from Inductive Automation, LLC. Human Factors researchers provided input in the form of a human-machine interface design guide that was used to develop the control system interface. In addition, INL Fire Protection Engineers from INL's Applied Engineering Division provided a system design for the integration of new flame detectors with both the TEDS control system and the facility fire alarm system. Both projects were started in Fiscal Year 2023 and completed by June 2024. These upgrades close corrective actions implemented following the oil spill incident in August 2021 and improve the operability and safety of the system.

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Modifications to the Thermal Energy Distribution System (TEDS)

BACKGROUND

The Thermal Energy Distribution System (TEDS) was designed in 2019, and construction commenced in 2020. Initial system operations began in 2021 with formal shakedown testing in August of that year. During that testing, a system perturbation caused oil to spew from a high-point vent and contact hot piping. The resulting oil vapor filled the high bay housing TEDS and damaged electronic equipment. An incident investigation classified the event as a near miss since no one was hurt and equipment damage was minor.

One of the resulting corrective actions was to have a formal fire hazard analysis completed. The fire hazard analysis pointed out a National Fire Protection Association code requirement to have a flame detection system that can shut down the system in the event of a fire.

The incident investigation also pointed out that the National Instruments LabVIEW software being used to control the system was not appropriate for the scope and scale of a system like TEDS. A recommended action was to identify an appropriate industrial control system that meets safety and operating requirements.

Contracts were issued to external firms to install the flame detection system and integrate it with the facility fire alarm system and to design and integrate a new control system based on Opto 22 hardware and Inductive Automation's Ignition software. These modifications to TEDS enable operation without having a smoke detector/fire suppression system impairment in place and prevent the need to have a roving fire watch during system operation.

DISCUSSION

This section will present a brief overview of both the control system and flame detection system upgrades.

Flame Detection

Since the nominal operating temperature for TEDS (315°C) is above the flash point for Therminol 66, the fluid must be treated as a flammable liquid. The fire hazard analysis identified that the National Fire Protection Association code requires a flame detection system be in place to shut the system down in the event of a fire.

Idaho National Laboratory (INL) Fire Protection Engineers from the Facilities and Site Services Applied Engineering Division designed a fire alarm system around Det-Tronics multispectrum infrared flame detectors. Six of these detectors were required to cover all areas of TEDS where leaks and fires are a possibility. In addition, the fire protection engineer designed a fire alarm system with dry contacts to provide emergency stop functionality to the TEDS controls and inputs/outputs to interface with the facility fire alarm system.

A manufacturer's representative for Det-Tronics provided technical input on locations for the flame detectors to ensure maximum coverage and minimum probability for false alarms. Figure 1 shows the flame detectors chosen for TEDS.

Figure 1. Det-Tronics multispectrum IR flame detector.[a]

Control System

The control system for TEDS was initially built with PXi-based hardware and LabVIEW supervisory control and data acquisition software, both from National Instruments. This control system architecture is ideal for many laboratory-scale research systems. It is easily configurable, the programming is based on a graphical user interface, and it is ubiquitous across INL. All controls in this architecture exist within the LabVIEW software. If the computer crashes, it is possible for the system to continue to operate because there are no inputs or outputs from the software.

TEDS is an industrial-scale prototype system with hazards that are outside the scope of many experimental systems in laboratory settings. A control system architecture based on programmable logic controllers or dedicated controls processors provides a safer platform from which to operate a system with hazardous energy. The dedicated controls processor can be programmed with safety shutdowns for the system that place it in a safe configuration in the event of a leak or a fire.

Opto 22 was chosen for the hardware side of the new controls. Opto 22 groov EPIC is an edge-network programmable controller. It is more robust in terms of safety functionality than the National Instruments system TEDS originally had, and it is more flexible than a conventional programmable logic controller used in many commercial/industrial processes. The Opto 22 hardware is used across multiple systems within the Dynamic Energy Transport and Integration Laboratory. A common control system architecture allows easier integration of these systems. In addition, the Opto 22 hardware is easier to pair with a digital twin or other devices under research.

[a] https://www.det-tronics.com/products/x3302-multispectrum-infrared-hydrogen-flame-detector

Figure 2. Typical Opto 22 EPIC controller.[b]

The new supervisory control and data acquisition software, Inductive Automation's Ignition, provides a modern user interface. The control screens use design guidance from INL's Human Factors group to minimize human performance errors—color-coded valves (green = open, red = closed), color-coded controllers (green = running, red = stopped). Figure 3 presents the main control screen.

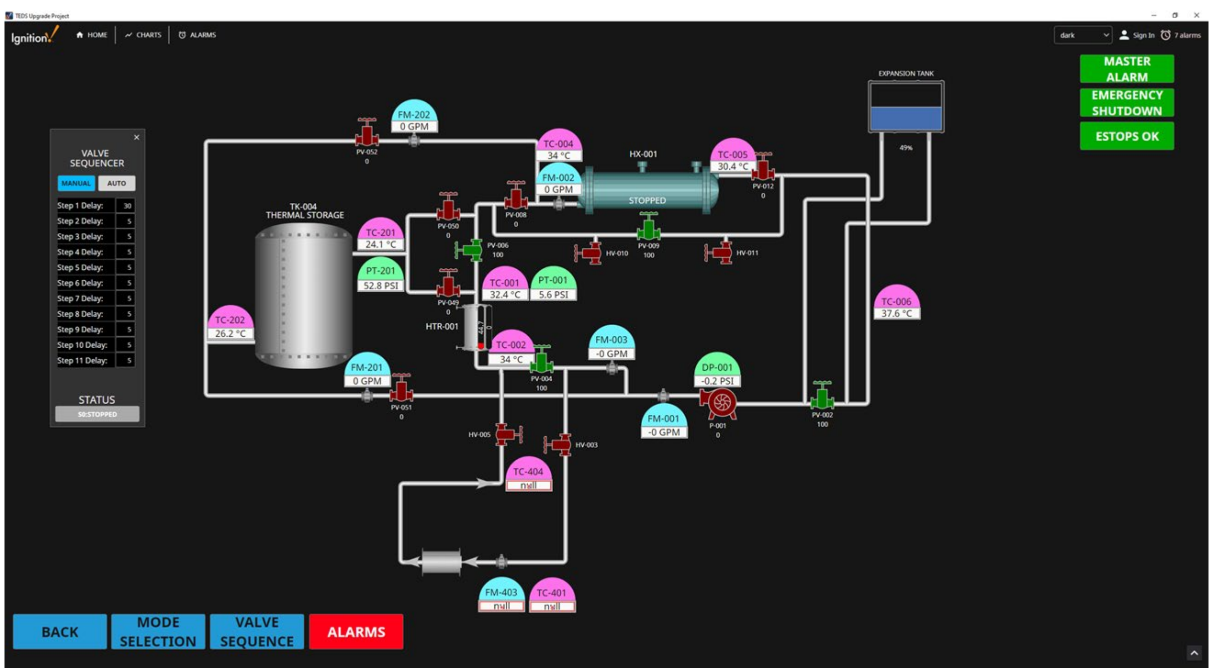

Figure 3. Main TEDS control screen.

[b] https://www.opto22.com/products/groov-epic-system/what-is-epic

CONCLUSION

Contracts to upgrade TEDS, including the installation of a flame detection system and an updated control system, were initiated and completed. The upgrades were necessary to ensure TEDS' compliance with applicable National Fire Protection Association codes and to improve the operability and safety of the system. Previously, operating TEDS at temperatures above the flash point of the working fluid required the fire alarm system to be impaired and augmented with a roving fire watch. These upgrades also provide the primary step toward operating without a fire alarm system impairment and represent progress toward automated and economical long-term operation of the system unattended.