

# **Rigorous Online Process and Economic Performance Monitoring for Gas Processing Facilities**

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## **ABSTRACT**

With the current growth of the midstream industry, gas processing companies are increasingly focused on acquiring, expanding, and constructing new gas processing facilities. This diverts the attention of process engineers and operations management towards working on facilities design and commissioning. The result is limited time available for troubleshooting and analysis of plant performance.

Enogex, LLC has experienced many of the above challenges. Enogex discussed with eSimulation, Inc. if the existing web-based optimization systems, installed at their cryogenic plants, could be enhanced to proactively address performance degradation.

Working with Enogex, eSimulation developed a new tool called the “Process Engineer Support Package” which provides rigorous process performance information. This web based solution allows users to remotely monitor plant and equipment performance for their facility. It also allows them to compare plant operating and economic performance against previous operating periods. The solution includes statistical analysis, charting, and downloading of data required for detailed analysis of plant performance.

The paper will describe situations whereby standard process analysis techniques failed to identify the source of the problem and how a rigorous analysis was able to avoid process downtime. The paper will also include a detailed description of the rigorous equipment performance analysis that is provided by eSimulation on a 24/7 basis.

## **BACKGROUND**

Enogex has employed eSimulation's electronic Process Monitoring (ePM) system since July 2000, which collected data and calculated equipment performance parameters and made the results available securely and remotely via the internet. This technology was then upgraded to the eSimOptimizer<sup>SM</sup> technology which uses this plant data to run optimization cases to improve value at the plant by incorporating the existing prices and aggregated contract system and suggesting moves on various control handles.

Over the years the natural gas industry has seen strong liquid margins and higher demand for ethane due to which fuel vs. recovery optimization has been replaced by maximizing liquid recoveries while processing maximum throughput. To maximize liquid recoveries and throughput meant not just running the plants to their process limits as guided by the optimizer but also direct efforts to swiftly troubleshoot process problems, minimize equipment efficiency losses and processing downtime.

This led to brainstorming to improve the present optimization package that eSimulation provided and convert it into an automated tool to monitor plant performance and troubleshoot problems.

## **OBJECTIVE**

The goal was to develop a tool which would easily spot plant and equipment issues, value bottlenecks and also supplement process and equipment data in order to troubleshoot these problems. To identify the process issues automatically, eSimulation used industry standard Key Performance Indicators (KPI) like liquid recoveries, fuel to feed ratio, natural gas GPM and BTU calculations. These KPIs, although very useful in determining process efficiency disruption, do not pinpoint the problem and do not provide a complete picture of what is happening at the plant.

To find the source of the disruption, the data needs to be analyzed. Due to the dynamic nature of the process, data from each tag representing a plant transmitter depends on some other tag. The use of a commercial data historian is hence limited as the dependence of one tag reading over the other is not easily understood. Spreadsheets allow ease of calculations but do not always reveal the existing problems easily.

The solution to this issue was a need to represent all this data over a process flow diagram (PFD) which helps the engineer or trained operator to quickly spot issues. Also, to help confirm these issues this tool needed a function to compare the plant between two different historical periods, like comparing the problem ridden process data with some good data from the past.

This led to the development of a complete online package called 'Process Engineer Support Package' (PESP) which helps the process engineers and operations management by providing critical process and equipment performance data laid out interactively on the plant PFD.

## IMPLEMENTATION:

The implementation of the Process Engineer Support Package at a new facility would require collection of process data, running simulations on this data and displaying the results online on the plant PFD.

### 1. DATA COLLECTION:

The data is collected using an industry standard OPC Client called the eSimulation DataPump™ which communicates to any DCS, PLC or SCADA system via the OPC server. The communication is once every minute and sends a five minute averaged data for each transmitter reading using a secure web transaction to eSimulation's website. The data from each transmitter is uniquely identified and is associated with a value, timestamp and an OPC quality which is stored on eSimulation's Structured Query Language (SQL) database. Figure 01 gives a schematic representation of how eSimulation gathers data from a facility.

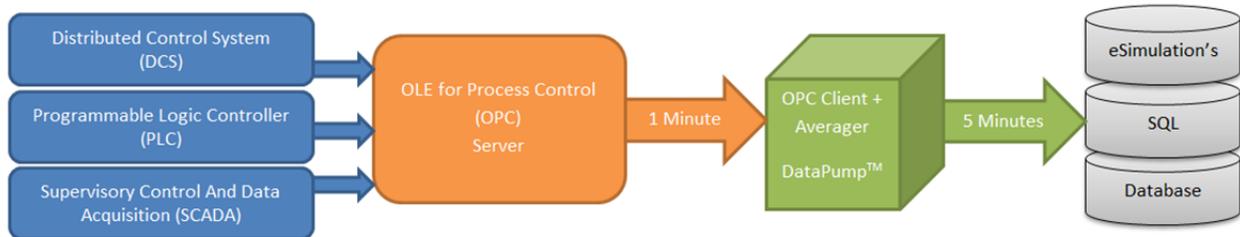


Figure 01: Data acquisition from a DCS/PLC/SCADA system and stored on eSimulation's SQL Database.

The raw data that eSimulation collects are primarily from flow transmitters, pressure transmitters, temperature transmitters and chromatographs; some of these readings are processed on calculations scripts to evaluate KPIs, gas BTU, product constraints etc.

eSimulation uses the data from the plant to perform a series of material balance calculations and generates a live profit value calculation based on aggregated product contracts and the current gas and liquid pricing. These value numbers are used to track the value generated at the plant. Figure 02 shows an example of profit value based material balance calculations on a cryogenic facility. These value numbers can be compared between timeframes to check the performance of the plant and identify the value drivers.

## Plant Performance for DemoPlant

Time Period:

Last 30 Days

1/1/2011 to 1/31/2011

PLANT DATA	VALUE	UOM	PRICES	VALUE	UOM	MARGINS	VALUE	UOM
INLET GAS FLOW	54.98	MMSCFD	GAS BUY PRICE	3.95	\$/MMBTU	ETHANE MARGIN	23.58	cents/gal
RESIDUE GAS FLOW	48.06	MMSCFD	GAS SELL PRICE	4.20	\$/MMBTU	PROPANE MARGIN	83.49	cents/gal
FUEL GAS FLOW	0.80	MMSCFD	ETHANE PRICE	56.00	cents/gal	ISOBUTANE MARGIN	123.46	cents/gal
INLET LINE PRESSURE	896.95	PSIG	PROPANE PRICE	126.00	cents/gal	n-BUTANE MARGIN	115.69	cents/gal
RESIDUE LINE PRESSURE	1,003.36	PSIG	ISOBUTANE PRICE	178.00	cents/gal	GASOLINE MARGIN	152.88	cents/gal
Ambient Temperature	51.38	DEG. F	n-BUTANE PRICE	161.00	cents/gal			
			GASOLINE PRICE	204.50	cents/gal			
			PRODUCT T&F PRICE	3.78	cents/gal			

COMPONENTS	Conversion		INLET GAS				RESIDUE GAS				NGL			
	Gal/lb Mole	HHV BTU/scf	MOL %	GPM	GAL/DAY	BTU/SCF	MOL %	GPM	GAL/DAY	BTU/SCF	GAL/DAY	LV %	RECOVERY %	PRODUCT VALUE (\$/DAY)
C1	6.4170	1,010.00	84.75	14.33	787,990.15	855.97	96.51	16.32	784,476.06	974.75	3,514.09	0.90	0.44	0.00
C2	10.1187	1,769.60	8.15	2.17	119,478.43	144.25	2.06	0.55	26,267.64	36.52	93,210.79	48.96	77.91	48,539.78
C3	10.4243	2,516.10	3.76	1.03	56,784.22	94.65	0.02	0.01	320.48	0.61	56,463.74	29.73	99.44	69,305.17
IC4	12.3830	3,251.90	0.48	0.16	8,585.38	15.57	0.00	0.00	0.10	0.00	8,585.28	4.51	100.00	14,274.04
NC4	11.9350	3,262.30	0.98	0.31	16,921.26	31.93	0.00	0.00	0.58	0.00	16,920.68	8.90	100.00	27,129.27
IC5	13.8540	4,000.90	0.22	0.08	4,486.98	8.94	0.00	0.00	1.26	0.00	4,485.72	2.35	99.97	9,124.04
NC5	13.7110	4,008.90	0.21	0.07	4,074.88	8.22	0.00	0.00	0.00	0.00	4,074.88	2.14	100.00	8,288.27
C6PLUS	16.5166	4,755.90	0.18	0.08	4,416.72	8.75	0.00	0.00	1.68	0.00	4,415.03	2.32	99.96	8,978.57
CO2	6.4216	0.00	0.71	0.12	6,598.19	0.00	0.76	0.13	6,213.42	0.00	384.77	0.19	5.74	0.00
N2	4.1643	0.00	0.56	0.06	3,361.08	0.00	0.64	0.07	3,361.08	0.00	0.00	0.00	0.00	0.00
TOTAL	-	-	100.00	3.91	214,747.88	1,168.29	100.00	0.56	26,591.75	1,011.89	192,054.99	100.00	-	185,639.14

PLANT ECONOMICS	VALUE	UOM
INLET GAS COST	256,975.19	\$/day
RESIDUE GAS VALUE	208,761.32	\$/day
FUEL GAS COST	3,462.34	\$/day
POWER COST	4,613.60	\$/day
SHRINKAGE COST	48,213.87	\$/day
NGL PRODUCT VALUE	185,639.14	\$/day
TOTAL VALUE	129,349.33	\$/day

Figure 02: Plant performance calculations based on the transmitter readings from the plant and the latest gas and liquids pricing.

## 2. PROCESS SIMULATION:

eSimulation employs the eSimOptimizer<sup>SM</sup> simulation/optimization technology to do process equipment efficiency calculations along with its process optimization service.

The eSimOptimizer engineering model allows the user to develop a complete thermodynamic model of the gas processing plants. This is done like any commercial simulation and modeling software by linking one process unit to another to develop a complete model of the gas processing facility. The basic thermodynamic models that this technology provides are stream, splitter, mixer, flash, rigorous expander, rigorous centrifugal & reciprocating compressor, motor models and a profit model to configure gas and NGL contract systems. It allows a user to run series of Solution Cases using a non-linear algebraic solver to fit plant data, perform simulation case studies, find sensitivities value for control handles and to optimize the facility.

The various Solution Cases included in this package are Parameter/Reconcile, Simulate/Optimize and Sensitivity.

The Parameter/Reconcile case allows the user to fit the plant transmitter readings in the model and to calculate various performance indicators for process equipment like heat transfer coefficient for exchangers, efficiencies for expander and compressors, etc. Since the overall model is connected to a profit model, this solution also evaluates the monetary value generated at the plant. This case also evaluates how closely the solver fits to other floating transmitter readings in the model to calculate biases on the readings and offsets on equipment performance derived from datasheets and performance curves. The difference between the parameter case and reconcile case is the parameter case completely depends on the transmitter readings while the reconcile case allows added degrees of freedom to compensate for bad readings and/or missing data from the plant.

The Simulate/Optimize case allows the user to add degrees of freedom to the solver which allows the solver to move these handles independently while keeping the model offsets and biases constant. These degrees of freedom represent control handles at the plant which the operators use to run the plant. Typical control handles on a cryogenic gas processing facility are the tower pressure, bottoms temperature, reflux flow etc. The difference between the simulate and optimize case is the simulate case generally doesn't have an aimed objective function and relates to what-if scenario cases to be evaluated on the model whereas the optimize case has set objectives like increasing profit, reducing out of bound product specifications etc. Figure 03 displays an optimization screen for a gas processing plant which the operators use to make the process moves.

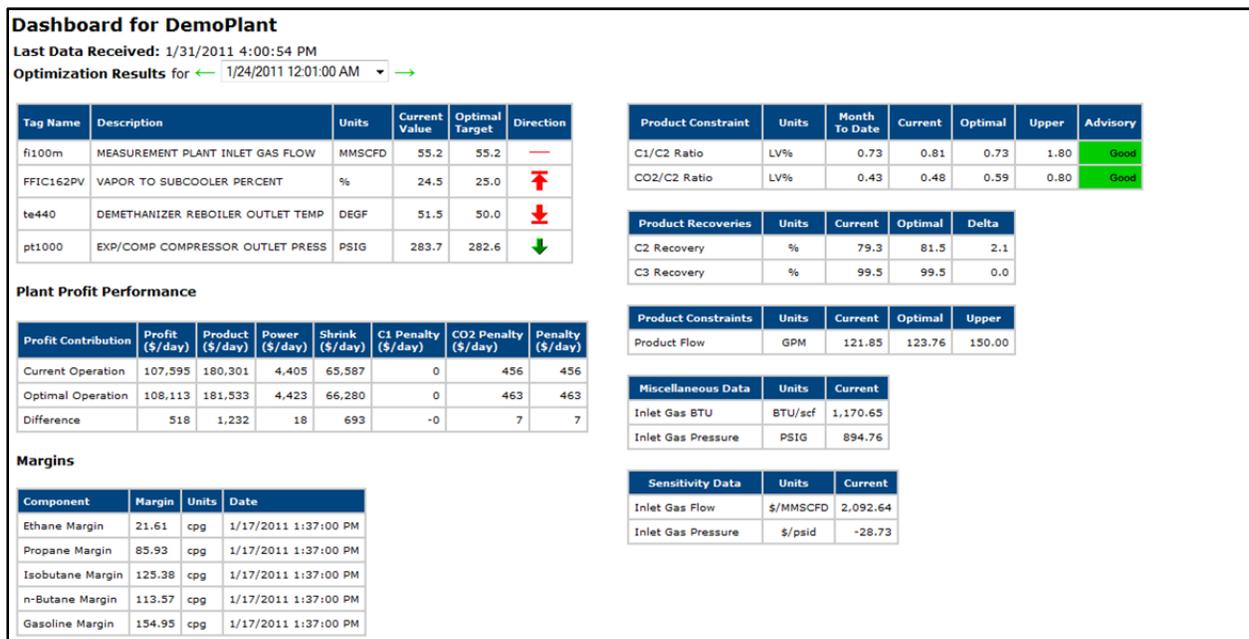


Figure 03: A typical optimization screen with optimization moves on each control handle is displayed.

The Sensitivity case gives an estimate of the change in the objective function for a unit increase on a control handle; for example when the objective function is set to the total profit at the plant, the sensitivity for inlet pressure control will provide a value in dollar for a one psi increase in that value (\$/psi). Table 01 gives an example of sensitivity data on some control parameters.

Sensitivity Data	UOM	Value
Inlet Gas Flow	\$/MMSCFD	1,798.00
Inlet Gas Pressure	\$/PSID	69.14
Cold Separator Temperature	\$/degF <sub>(difference)</sub>	-211.42

Table 01: Sensitivity data on the plant inlet volume, inlet pressure and cold separator temperature.

The eSimOptimizer technology is run once every two hours on stored data and can write all equipment efficiencies, optimization targets for the control system, biases etc. for the averaged time period back to the database. The eSimulation web application uses this data from the database and displays the optimization and performance results on the website.

### 3. ONLINE PFD:

A PFD of the process is generated using Microsoft Visio software and this PFD is then displayed securely over the web. The web script allows the user to select time frames to refresh data on the PFDs averaged over the time selected. Visual layers are developed on the process flow diagram which allows the users to non-exclusively select between Flows, Pressure, Temperatures, Analyzers and Calculated Values. This makes the tool interactive and keeps the process flow diagram from being flooded with information. Some of the features it provides are as follows:

- Viewing plant data over a PFD for a user selected timeframe.
- Comparing plant operations between two distinct timeframes.
- Select between Flow, Pressure, Temperature, Analyzer and Calculated layers to remove unnecessary information from the view.
- Select transmitter readings to view data points and chart them for the selected time frame.
- One click statistical data available for each transmitter reading.
- Viewing unit performance for the selected period; comparing this data with design data either from datasheets or performance curves.
- Downloading data for individual tags or for all tags facility-wide in a comma separated value (CSV) format accessible in Microsoft Excel.

### FEATURES

The Process Engineer Support Package offers various tools for getting a macro level view to a micro level view of the plant and its performance on the same process flow diagram. The PESP offers many applications such as process overview, equipment maintenance, troubleshooting, operator & plant performance, etc. A typical Online PFD is displayed in figure 04.

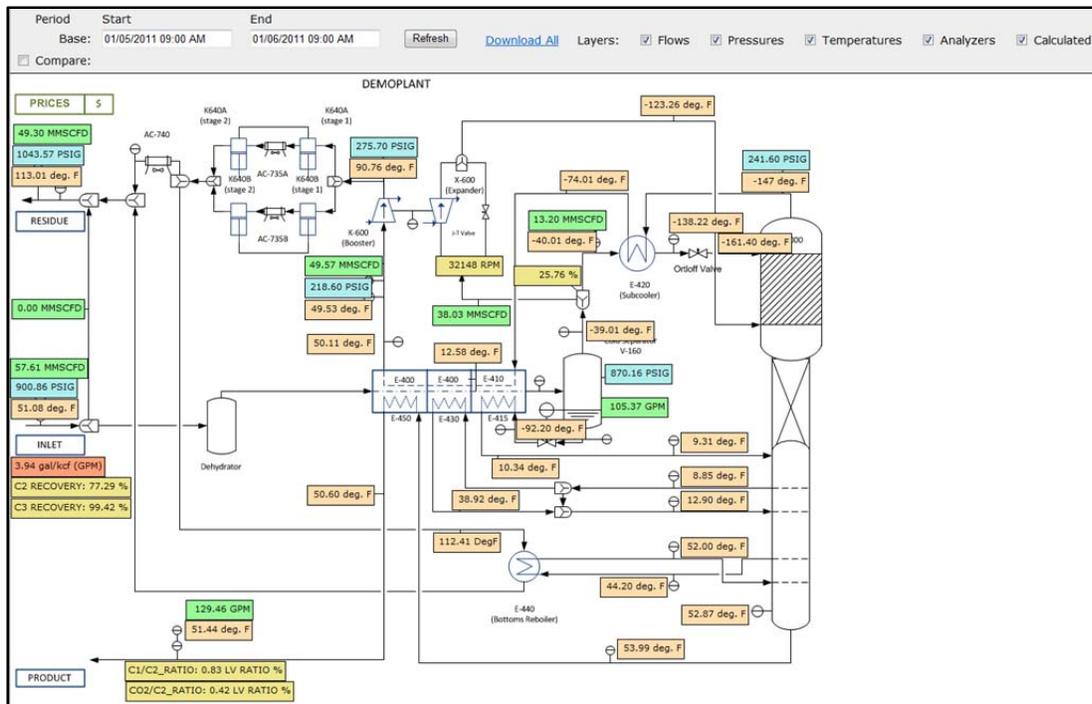


Figure 04: A typical Online Process Flow Diagram; notice all layers are selected on the top menu bar.

The user can isolate the data to be displayed on the PFD by selecting the layer that needs to be displayed. In figure 05 only the pressure transmitters are displayed by selecting only the pressure check box on the Menu Bar; this allows the user to do a pressure survey on the facility.

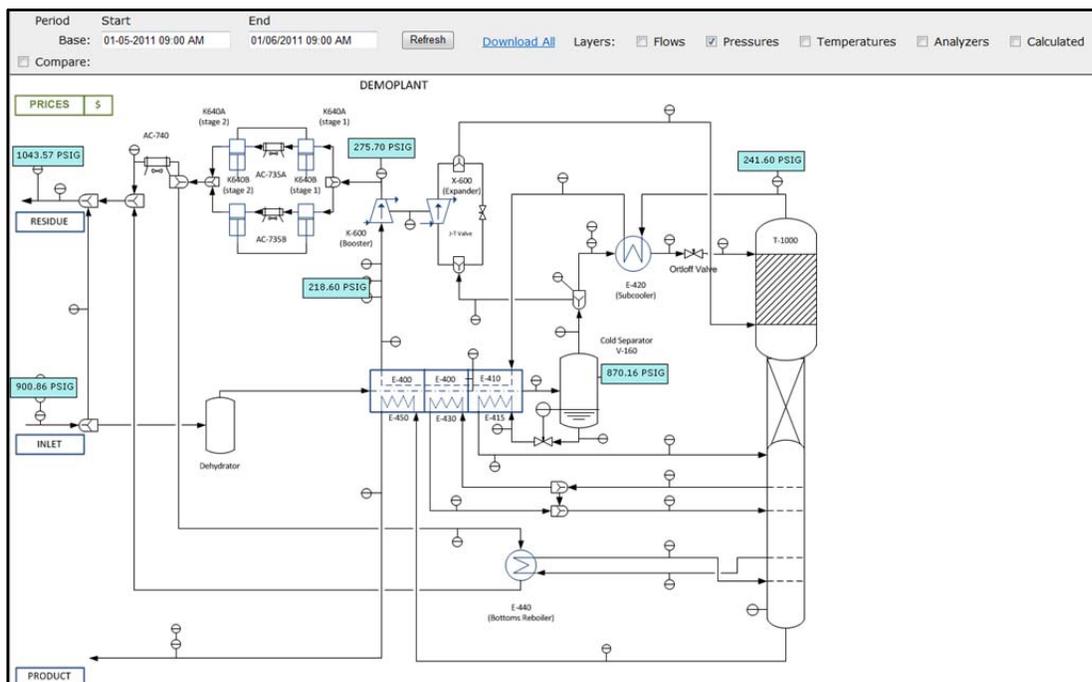


Figure 05: Only the Pressure tags displayed on the PFD; notice only the pressure layer selected on the top menu bar.

By selecting each individual transmitter tag the user can get access to the statistics on the data gathered from the transmitter, can view data points, chart and download them. In figure 06, by clicking the inlet flow transmitter FI100M; the user can see the range of gas processed between the selected periods; view standard deviation information and decide if the dataset is reliable to do performance calculations.

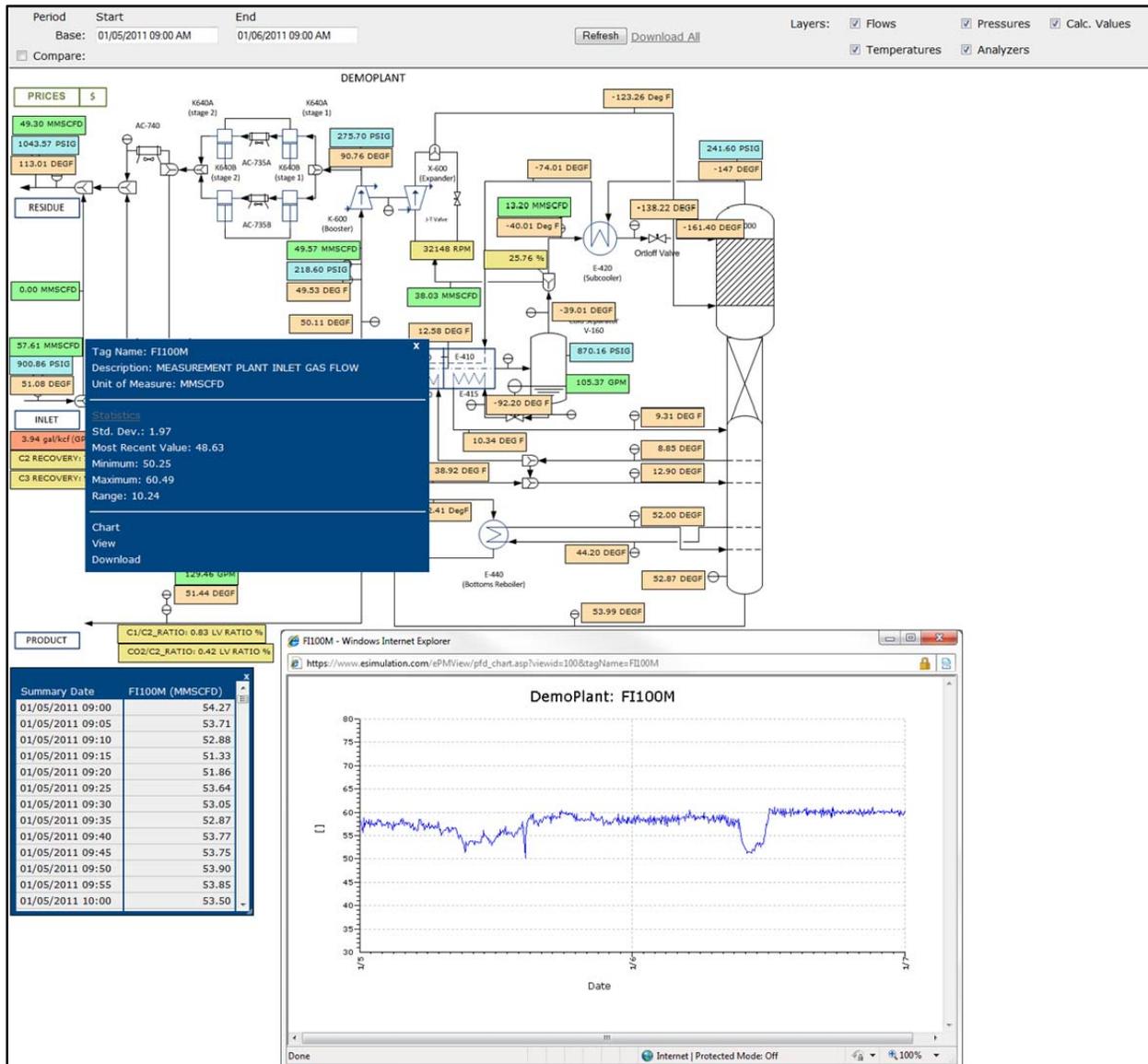


Figure 06: Each individual tag can be clicked to display information about the transmitter, view data, chart data and see statistics on the readings like standard deviation, range, minimum, maximum and most recent value.

The user can also select two time frames to compare plant performance as well as the individual equipment performance. All relevant data from the plant and the process equipment is compared online to swiftly troubleshoot problems as shown in figure 07.

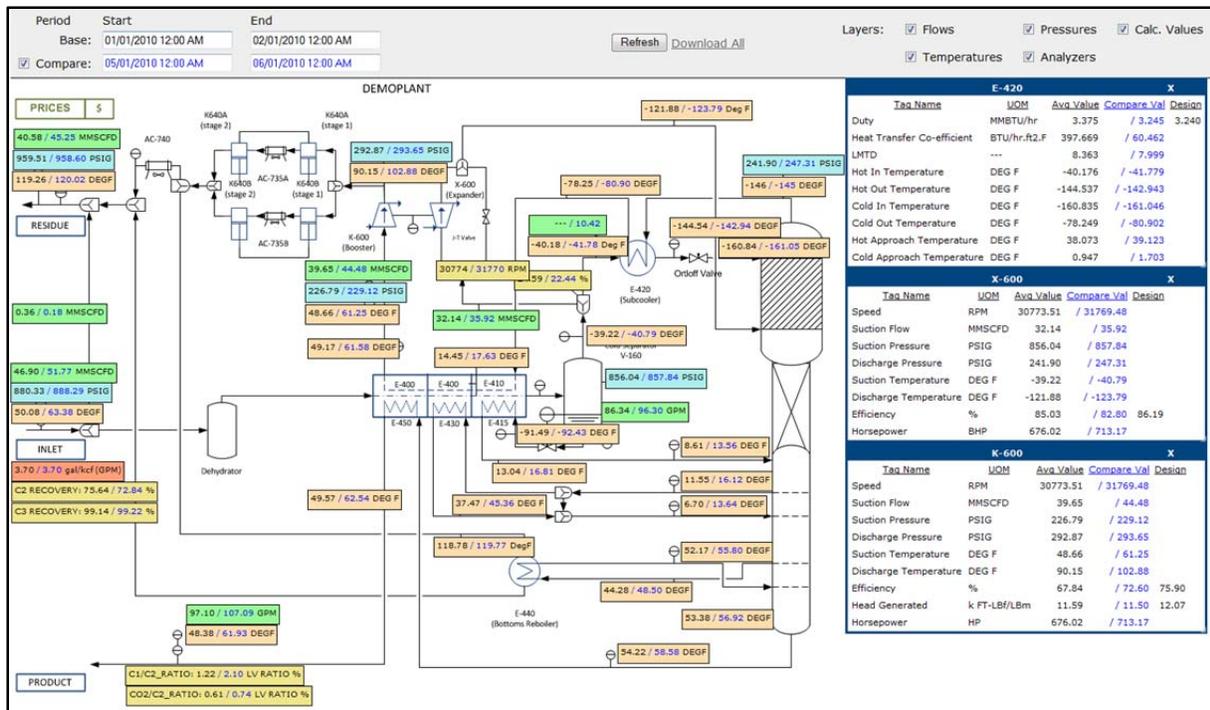


Figure 07: The data from two different time frames is compared on this display. The numbers displayed in black colored text are averaged over the base time frame and the ones in blue text are from the compared time frame.

## PROCESS APPLICATIONS

With the help of this tool eSimulation was able to provide timely guidance on a potential freezing situation in one of the reflux exchangers. The ethane recovery on the plant was dropping which was initially attributed to higher GPM gas being processed. Although when the data for the relevant period was loaded on the PFD and compared with identical conditions from the past as shown in figure 08, it showed the hot-side outlet temperature from the reflux exchanger being 25 degF warmer than the compared period. A quick plot of the duty across that exchanger for the relevant period showed a gradual drop in heat exchange. This was conveyed to the plant personnel, which was followed by a methanol injection and normal heat exchange resumed as plotted in Figure 09. A detailed value analysis as shown in Table 02 determined that the value recovered by timely troubleshooting this issue was worth \$ 2,875/day in the form of increased liquid recoveries.

Plant Performance	C2 Recovery	Inlet Rate	Fuel/Inlet rate
Baseline (10-25-2010 to 10-30-2010)	69.90%	125.51	1.73%
Post Troubleshooting (10-31-2010 to 11-02-2010)	73.19%	126.09	1.71%

Revenue Affects	Liquids	Shrink	Fuel	Total (\$/day)
	\$4,314	\$1,487	-\$47	\$2,875

Table 02: Value improvement after the troubleshooting effort.

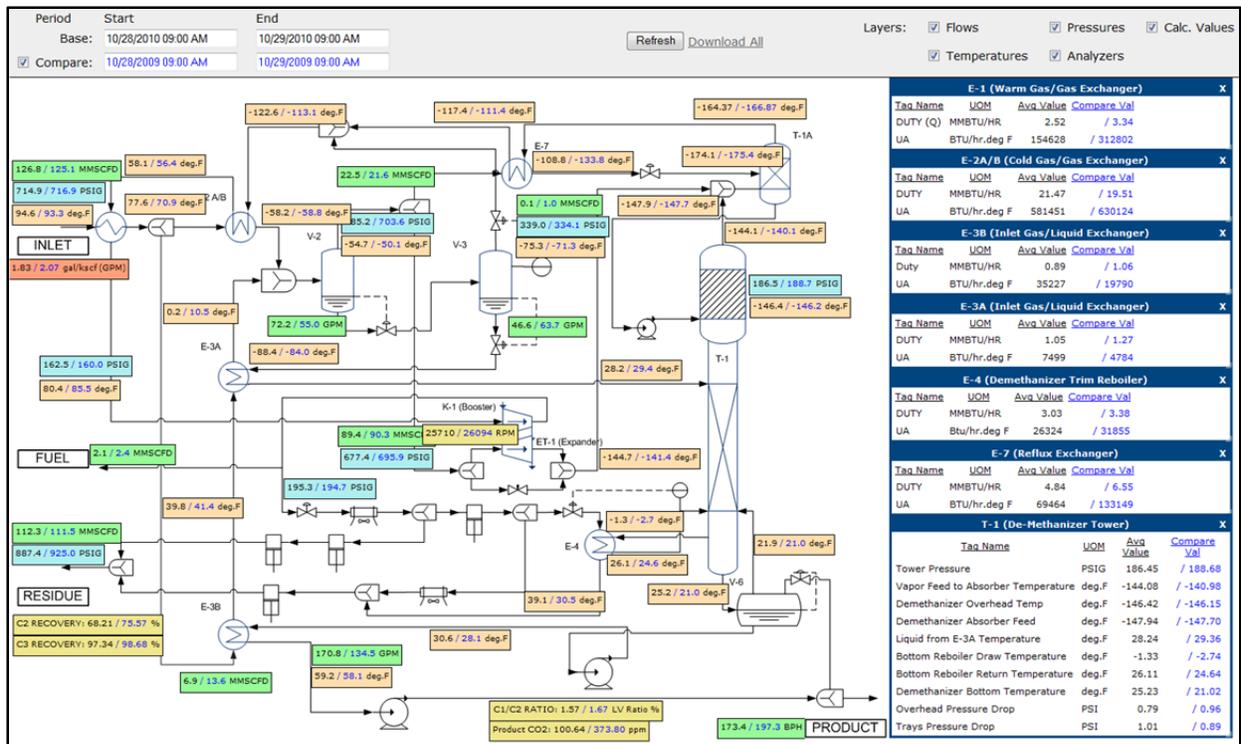


Figure 08: Comparing performance of the plant on datasets year apart detailing the issue on reflux exchanger E-7 in more detail.

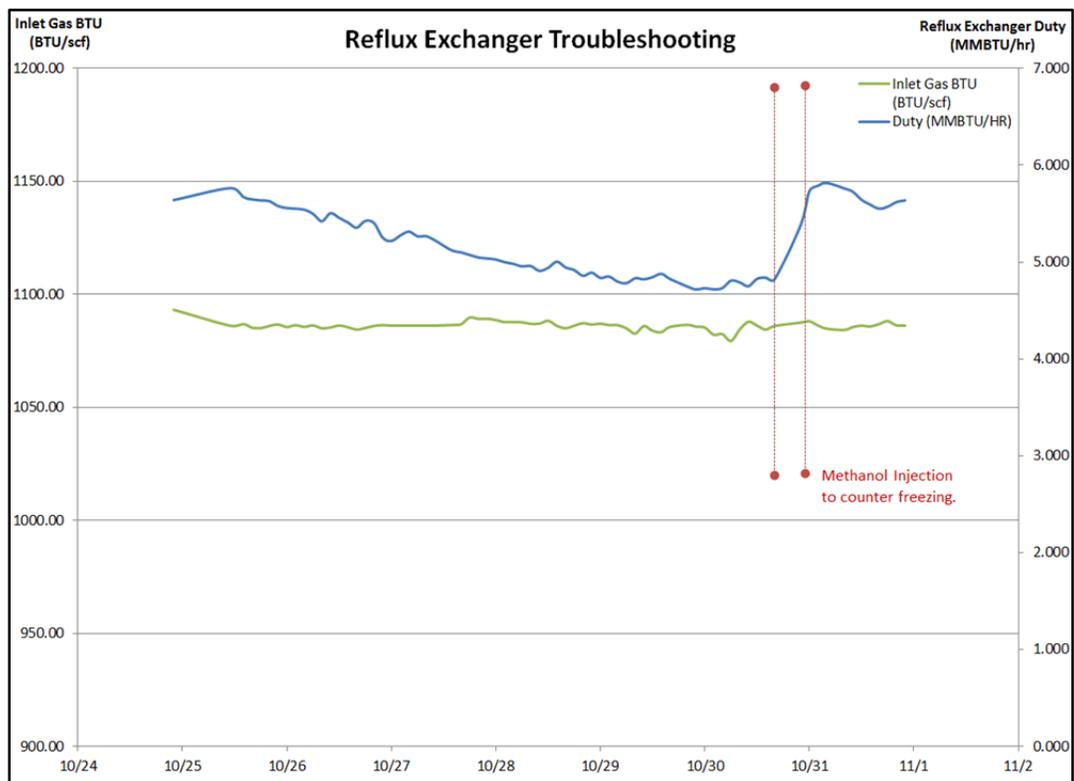


Figure 09: Reduction of heat exchange due to freezing and increased heat exchange after methanol treatment.

This tool has also helped finding performance issues in identically designed cryogenic facilities by comparing process data of each cryogenic train side-by-side. Figure 10 displays the temperature difference between the two trains is carried forward from the gas/gas exchanger hot outlet, to the cold separator, followed by the expander and into the tower setting up a different temperature profile on the tower and causing a 2.7% lower ethane recovery on the second train compared to the first. The preliminary pressure drop analysis on the plant has shown a larger drop prior to the gas/gas exchanger on the second train compared to the first. Steady state simulations on the plant data has shown a lower heat exchange on the gas/gas exchanger on second train calculated at 3.72 MMBTU/hr compared to the first train gas/gas exchanger at 3.84 MMBTU/hr.

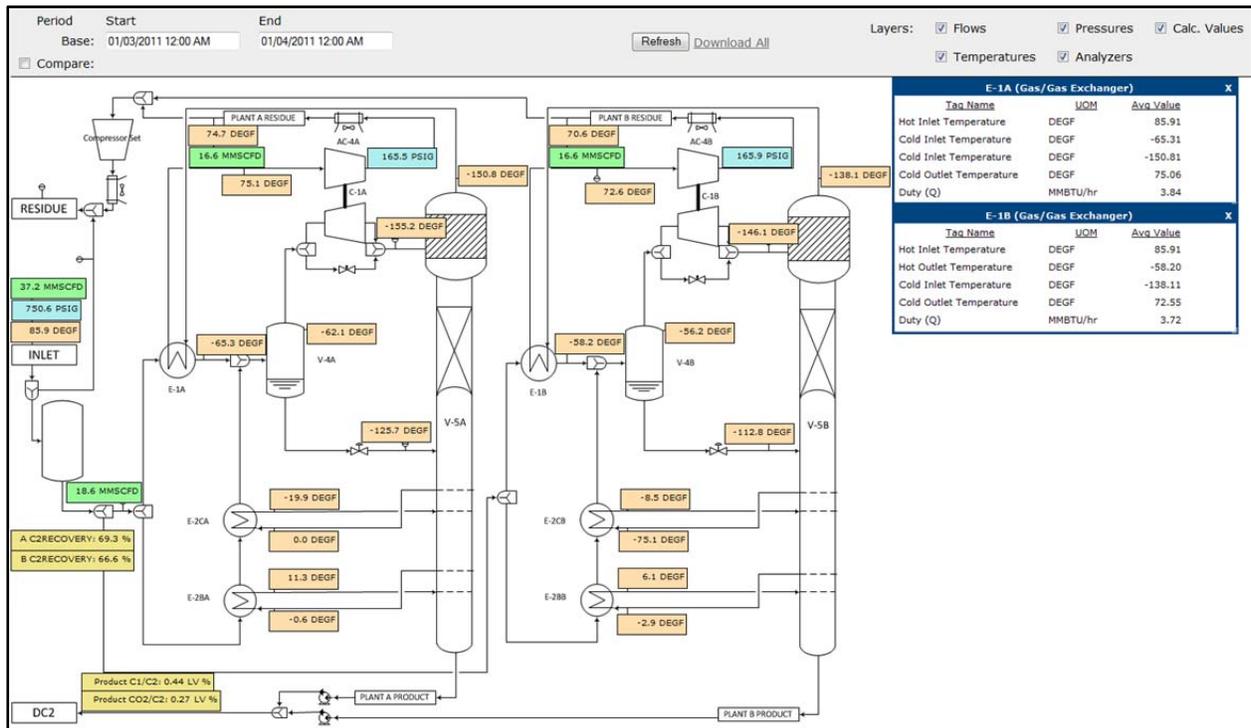


Figure 10: The data from two train cryogenic facilities is compared to show how differently they are operated and also to find transmitter issues.

This tool has been easily extended to liquids fractionation systems as shown in figure 11. Product specifications like vapor pressure can be monitored every two hours based on the simulation calculations. The user can also check the detailed component analysis of the fractionated product by clicking the analyzer block to see how close the fractionation plant is run to the specifications set for the product.

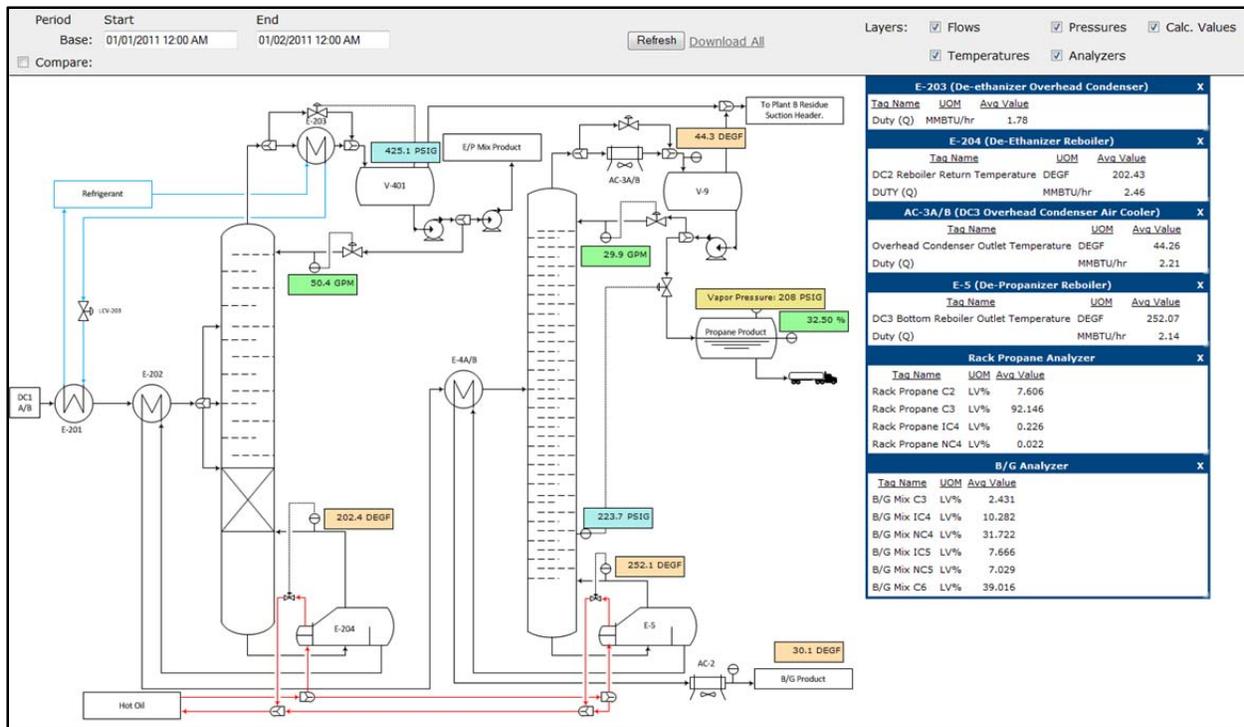


Figure 11: The fractionation train is displayed on this PFD monitoring the averaged rack propane vapor pressure and its detailed analysis.

eSimulation was also able to find maintenance issues with residue reciprocating recompressors; where the PESP tool found a discrepancy in the cylinder temperatures on the same stage of compression. The reciprocating compressor valve had lost good sealing and leaked the heated gas back into the compression process, where it got heated again and that resulted in a higher temperature in the cylinder.

C-001F		
Tag Name	UOM	Avg Value
Flow	MMSCFD	0.00
Suction Pressure	PSIG	268.07
1st Stage Discharge Pressure	PSIG	512.30
2nd Stage Suction Pressure	PSIG	506.28
Discharge Pressure	PSIG	960.50
Cylinder 1 Temperature	deg F	227.73
Cylinder 3 Temperature	deg F	219.70
Cylinder 5 Temperature	deg F	220.04
Inter Cooler Inlet Temperature	deg F	219.52
Cylinder 2 Temperature	deg F	211.69
Cylinder 4 Temperature	deg F	205.45
Cylinder 6 Temperature	deg F	208.68
Speed	RPM	875
Vibrations 4022	mil	42.41
Vibrations 4203B	mil	0.00
Vibrations 4025	mil	94.32
Turbo Vibrations	mil	0.00

Figure 12: There was an 8 degF change in the cylinder 1 compared to cylinder 3 and 5 on the 1st stage of compression.

The PESP tool was used to find a process issue, where the product temperature specification of minimum 50 degF was being violated because a process switch from summer operation to winter operation was overlooked. Figure 13 compares this winter operation (base period) to the summer operation (compare period) and details the temperature profile around the product heater E-450.

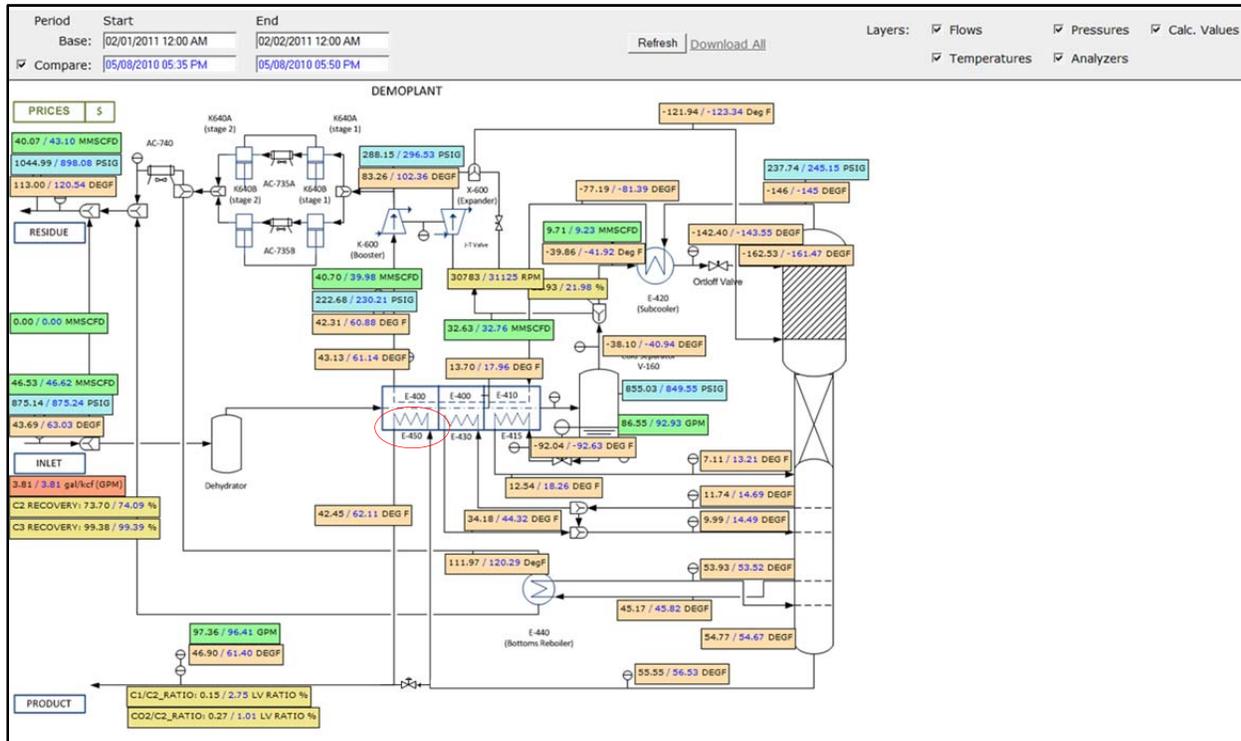


Figure 13: Product heater (E-450) performance compared between winter and summer operations.

The E-450 product heater is in service to keep the natural gas liquids temperature above the 50 degF limit and is designed to heat the product liquids by exchanging heat with the hot inlet gas. However due to the winter conditions the temperature of the inlet gas dropped to 44 degF and was incapable of heating the liquids above the 50 degF temperature limit. With the help of the bottom reboiler E-440, the bottoms temperature on the tower was kept at 55 degF by exchanging bottom reboiler liquids draw with the hot residue gas at 112 degF from the residue compressors. The product from the tower bottoms although at 55 degF then exchanged with this cold inlet gas at 44 degF and dropped below the specification of 50 degF. This was the reverse of what the heater was designed for and was also heating up the inlet gas which raised the cold separator temperature to affect the recoveries on the plant marginally. This information was then used to bypass NGL liquids around the product heater to meet the liquids temperature specification and from preventing the inlet gas to be heated up.

## ENHANCEMENTS:

eSimulation is considering various enhancements to the Process Engineering Support Package based on industry feedback, client recommendations, potential projects and tool shortcomings.

Some of these enhancements include:

- Run pre-configured simulations from the PFD; for example a user could change the throughput to the plant to see its effect on recoveries/equipment performance.
- Incorporating an automatic alerting system on the PFD to display process problems and maintenance requirement.
- Displaying equipment status for the selected period to determine if the selected equipment was in service.
- Updating material balance sheets automatically with simulation results.
- Displaying data on the plant P&IDs as an option versus the plant PFDs.
- Allowing sub-flow sheets for easy translation of information from one PFD to another.
- Unit conversions on the PFD for international clients and/or user preference.
- Automatically chart the current performance of compressors on the design curves online as represented in figure 14 (currently this feature is only available offline)

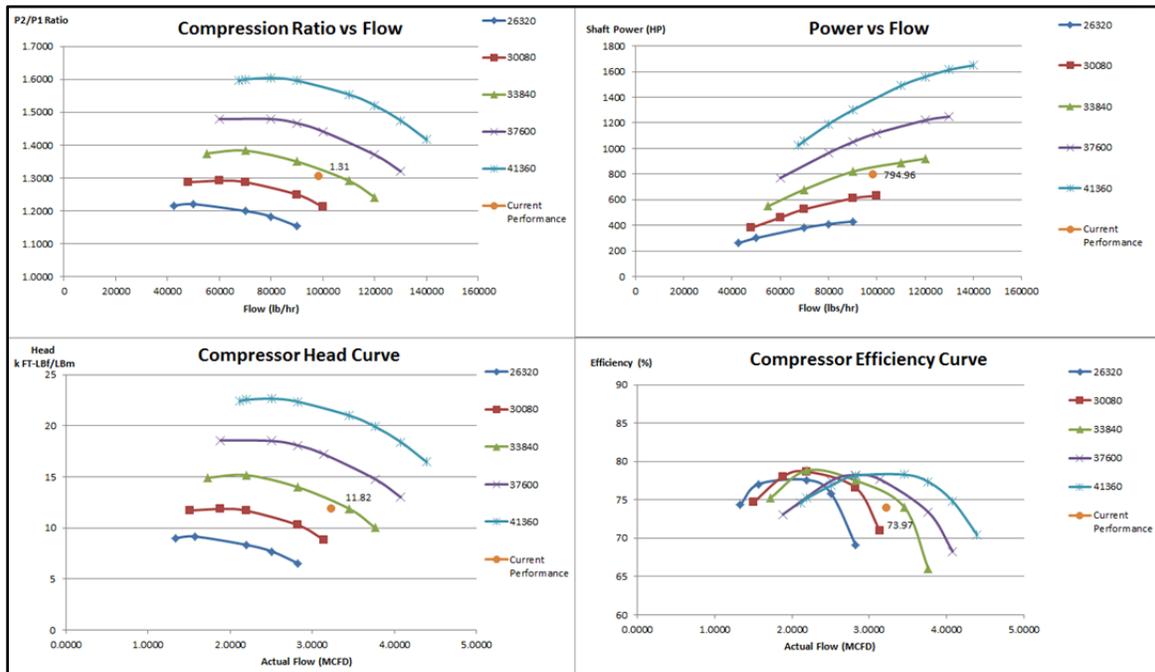


Figure 14: Performance of the booster compressor plotted offline on the performance curves provided by the vendor.

## CONCLUSION:

eSimulation with the valued guidance from Enogex has developed and validated the Process Engineer Support Package and has demonstrated a method to effectively monitor and/or troubleshoot issues common to a gas processing plant. Enogex has now employed this tool on five of their gas processing facilities in Oklahoma. The snapshots of the online PFDs are now included in the bi-weekly Value Capture Reports and are discussed with management and operators on regularly scheduled conference calls.