Ethylene Middle East Technology Conference

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Turning Big Data into Feed-to-Product Operating Envelopes for Business Efficiency

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Process Modelling with Parallel Coordinates for Big Data

Process Plants: Data and Challenges

Big Data Connection

Parallel Plot

Discovery and optimization

- Big data discovery
- Focus/drill down
- Optimization
- Hypothesis testing, answering questions

Parallel Coordinate Representation of Multivariate Process Envelopes

- Targeting specifications
- Economic operation
- Event prediction

Summary and Questions

Process Data Challenges

Data Size

Diverse sources

- Plant historian(s)
- Events
- Operation logs
- LIMS
- In/out material assays
- Fenceline/legal/custody meters
- Plant energy usage
- Rework
- Total failures

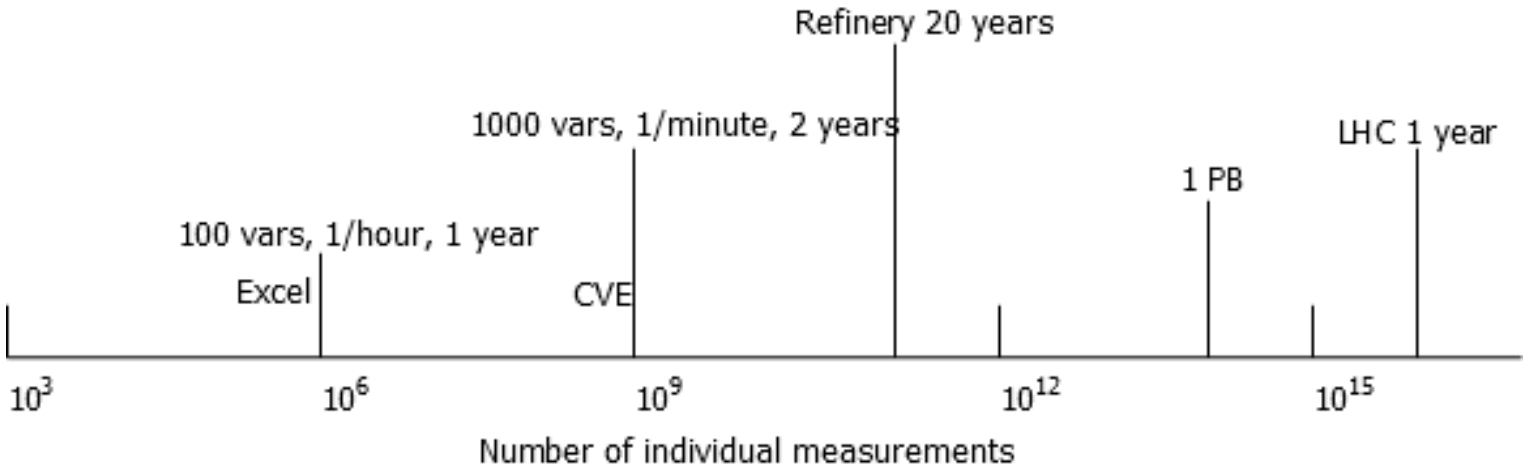
Results: Performance

- Yield, On-spec, Throughput, Uptime, Upsets
- Costs: Energy, Materials, Disposal, Maintenance
- Operation: Alarms, Controllability

Questions:

- What are the important variables and interactions?
- What are target ranges?
- Are there interactions do we didn't expect?
- Is our practice and understanding consistent with the process?
- Can we capture and replicate the best operation?

Data Scales



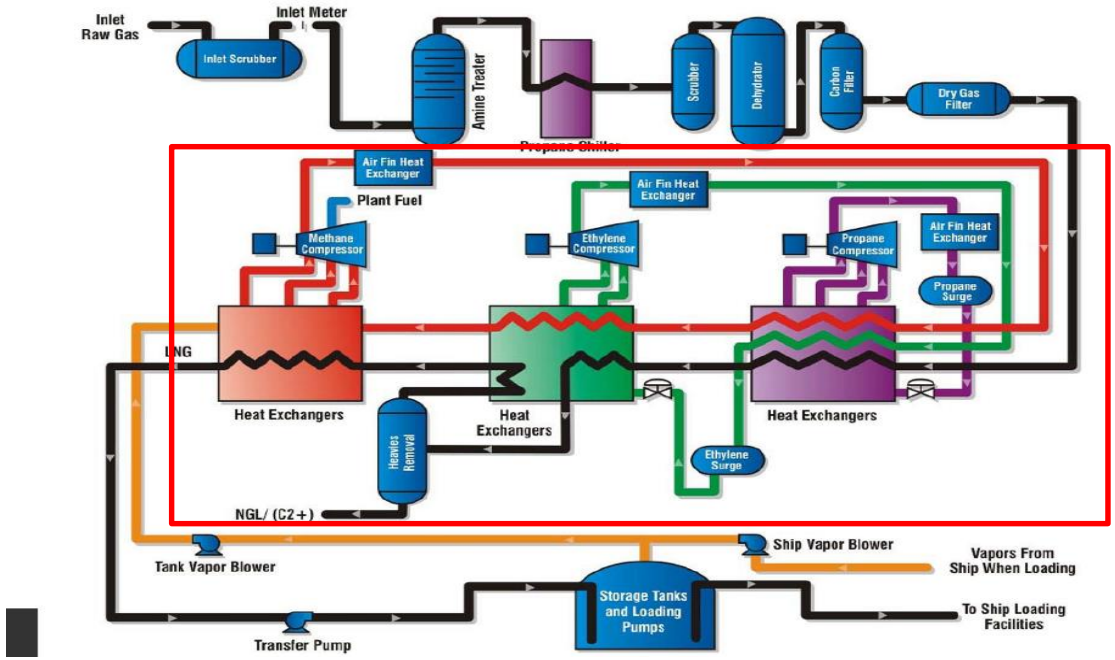
We look at smaller subsets:

- 10 variables around a unit
- How long? Maybe a couple weeks of data
- One or two lab measurements
- Hourly averages
- 3500 values: maybe that's enough….

Ignoring 99.99993% of the available data

What value is thrown away?

Example: Cryogenic Liquefaction and Separation

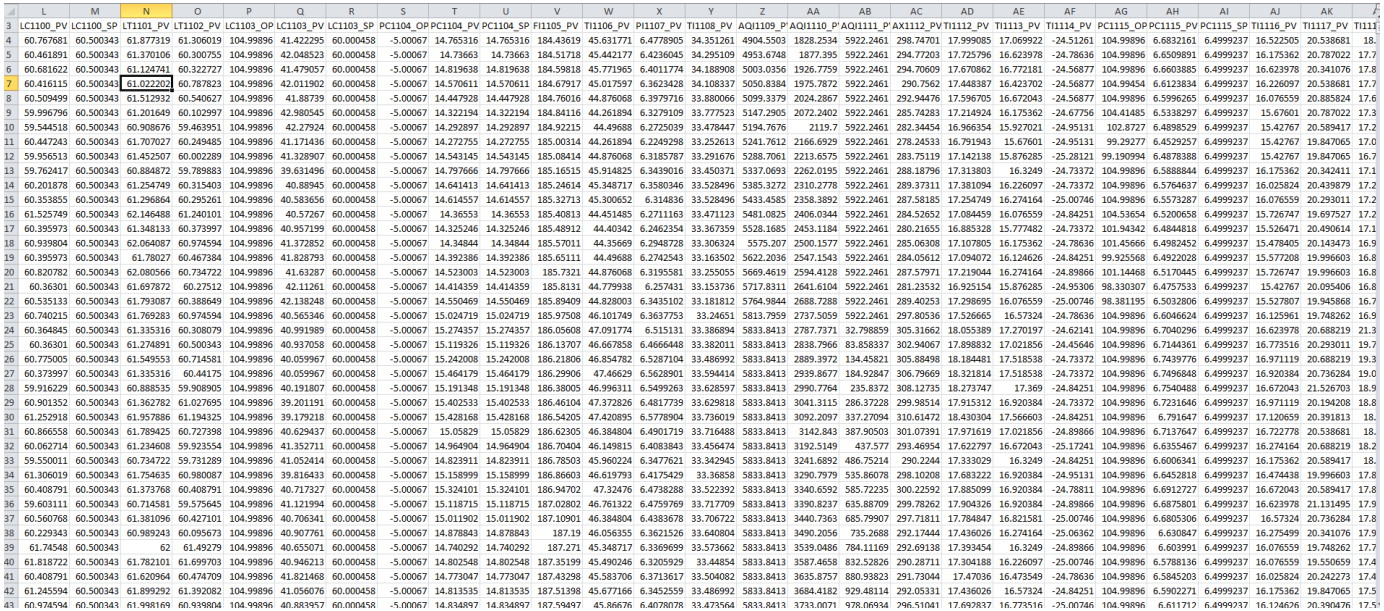


Engineers would focus on one unit or even just one piece of equipment

Deep process integration

Ideal operation: can we look at it all at once?

Data Today



	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
3	LC1100_PV	LC1100_SP	LT1101_PV	LT1102_PV	LC1103_OP	LC1103_PV	LC1103_SP	PC1104_OP	PC1104_PV	PC1104_SP	FI1105_PV	TI1106_PV	PI1107_PV	TI1108_PV	AQI1109_P'	AQI1110_P'	AQI1111_P'	AX1112_PV	TI1112_PV	TI1113_PV	TI1114_PV	PC1115_OP	PC1115_PV	PC1115_SP	TI1116_PV	TI1117_PV	TI111
4	60.767681	60.500343	61.877319	61.306019	104.99896	41.422295	60.000458	-5.000067	14.765316	14.765316	184.43619	45.631771	6.4778905	34.351261	4904.5503	1828.2534	5922.2461	298.74701	17.999085	17.069922	-24.51261	104.99896	6.6832161	6.4999237	16.522505	20.538681	18.
5	60.461891	60.500343	61.370106	60.300755	104.99896	42.048523	60.000458	-5.000067	14.73663	14.73663	184.51718	45.442177	6.4236045	34.295109	4953.6748	1877.395	5922.2461	294.77203	17.725796	16.623978	-24.78636	104.99896	6.6509891	6.4999237	16.175362	20.787022	17.7
6	60.681622	60.500343	61.124741	60.322727	104.99896	41.479057	60.000458	-5.000067	14.819638	14.819638	184.59818	45.771965	6.4011774	34.188908	5003.0356	1926.7759	5922.2461	294.70609	17.670862	16.772181	-24.56877	104.99896	6.6603885	6.4999237	16.623978	20.341076	17.8
7	60.416115	60.500343	61.022202	60.787823	104.99896	42.011902	60.000458	-5.000067	14.570611	14.570611	184.67917	45.017597	6.3623428	34.108337	5050.8384	1975.7872	5922.2461	290.7562	17.448387	16.423702	-24.56877	104.99454	6.6123834	6.4999237	16.226097	20.538681	17.7
8	60.509499	60.500343	61.512932	60.540627	104.99896	41.88739	60.000458	-5.000067	14.447928	14.447928	184.76016	44.876068	6.3979716	33.880066	5099.3379	2024.2867	5922.2461	292.94476	17.596705	16.672043	-24.56877	104.99896	6.5996265	6.4999237	16.076559	20.885824	17.6
9	59.996796	60.500343	61.201649	60.102997	104.99896	42.980545	60.000458	-5.000067	14.322194	14.322194	184.84116	44.261894	6.3279109	33.777523	5147.2905	2072.2402	5922.2461	285.74283	17.214924	16.175362	-24.67756	104.41485	6.5338297	6.4999237	15.67601	20.787022	17.3
10	59.544518	60.500343	60.908676	59.463951	104.99896	42.27924	60.000458	-5.000067	14.292897	14.292897	184.92215	44.49688	6.2725039	33.478447	5194.7676	2119.7	5922.2461	282.34454	16.966354	15.927021	-24.95131	102.8727	6.4898529	6.4999237	15.42767	20.589417	17.2
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13	59.762417	60.500343	60.884872	59.789883	104.99896	39.631496	60.000458	-5.000067	14.797666	14.797666	185.16515	45.914825	6.3439016	33.450371	5337.0693	2262.0195	5922.2461	288.18796	17.313803	16.3249	-24.73372	104.99896	6.5888844	6.4999237	16.175362	20.342411	17.1
14	60.201878	60.500343	61.254749	60.315403	104.99896	40.88945	60.000458	-5.000067	14.641413	14.641413	185.24614	45.348717	6.3580346	33.528496	5385.3272	2310.2778	5922.2461	289.37311	17.381094	16.226097	-24.73372	104.99896	6.5764637	6.4999237	16.025824	20.439879	17.2
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25	60.36301	60.500343	61.274891	60.500343	104.99896	40.937058	60.000458	-5.000067	15.119326	15.119326	186.13707	46.667858	6.4666448	33.382011	5833.8413	2838.7966	83.858337	302.94067	17.898832	17.021856	-24.45646	104.99896	6.7144361	6.4999237	16.773516	20.293011	19.7
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33	59.550011	60.500343	60.734722	59.731289	104.99896	41.052414	60.000458	-5.000067	14.823911	14.823911	186.78503	45.960224	6.3477621	33.342945	5833.8413	3241.6892	486.75214	290.2244	17.333029	16.3249	-24.84251	104.99896	6.6006341	6.4999237	16.175362	20.589417	18.
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35	60.408791	60.500343	61.373768	60.408791	104.99896	40.717327	60.000458	-5.000067	15.324101	15.324101	186.94702	47.32476	6.4738288	33.522392	5833.8413	3340.6592	585.72235	300.22592	17.885099	16.920384	-24.78811	104.99896	6.6912727	6.4999237	16.672043	20.589417	17.8
36	59.603111	60.500343	60.714581	59.575645	104.99896	41.121994	60.000458	-5.000067	15.118715	15.118715	187.02802	46.761322	6.4759769	33.717709	5833.8413	3390.8237	635.88709	299.78262	17.904326	16.920384	-24.89866	104.99896	6.6875801	6.4999237	16.623978	21.131495	17.9
37	60.560768	60.500343	61.381096	60.427101	104.99896	40.706341	60.000458	-5.000067	15.011902	15.011902	187.10901	46.384804	6.4383678	33.706722	5833.8413	3440.7363	685.79907	297.71811	17.784847	16.821581	-25.00746	104.99896	6.6805306	6.4999237	16.57324	20.736284	17.8
38	60.229343	60.500343	60.989243	60.095673	104.99896	40.907761	60.000458	-5.000067	14.878843	14.878843	187.19	46.056355	6.3621526	33.640804	5833.8413	3490.2056	735.2688	292.17444	17.436026	16.274164	-25.06362	104.99896	6.630847	6.4999237	16.275499	20.341076	17.9
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40	61.818722	60.500343	61.782101	61.699703	104.99896	40.946213	60.000458	-5.000067	14.802548	14.802548	187.35199	45.490246	6.3205929	33.44854	5833.8413	3587.4658	832.52826	290.28711	17.304188	16.226097	-25.00746	104.99896	6.5788136	6.4999237	16.076559	19.550659	17.4
41	60.408791	60.500343	61.620964	60.474709	104.99896	41.821468	60.000458	-5.000067	14.773047	14.773047	187.43298	45.583706	6.3713617	33.504082	5833.8413	3635.8757	880.93823	291.73044	17.47036	16.473549	-24.78636	104.99896	6.5845203	6.4999237	16.025824	20.242273	17.4
42	61.245594	60.500343	61.899292	61.392082	104.99896	41.056076	60.000458	-5.000067	14.813535	14.813535	187.51398	45.677166	6.3452559	33.486992	5833.8413	3684.4182	929.48114	292.05331	17.436026	16.57324	-24.84251	104.99896	6.5902271	6.4999237	16.175362	19.847065	17.5
43	60.974594	60.500343	61.998169	60.939804	104.99896	40.883957	60.000458	-5.000067	14.834897	14.834897	187.59497	45.86676	6.4078078	33.473564	5833.8413	3733.0071	978.06934	296.51041	17.692837	16.773516	-25.00746	104.99896	6.611712	6.4999237	16.124626	20.390476	17.5

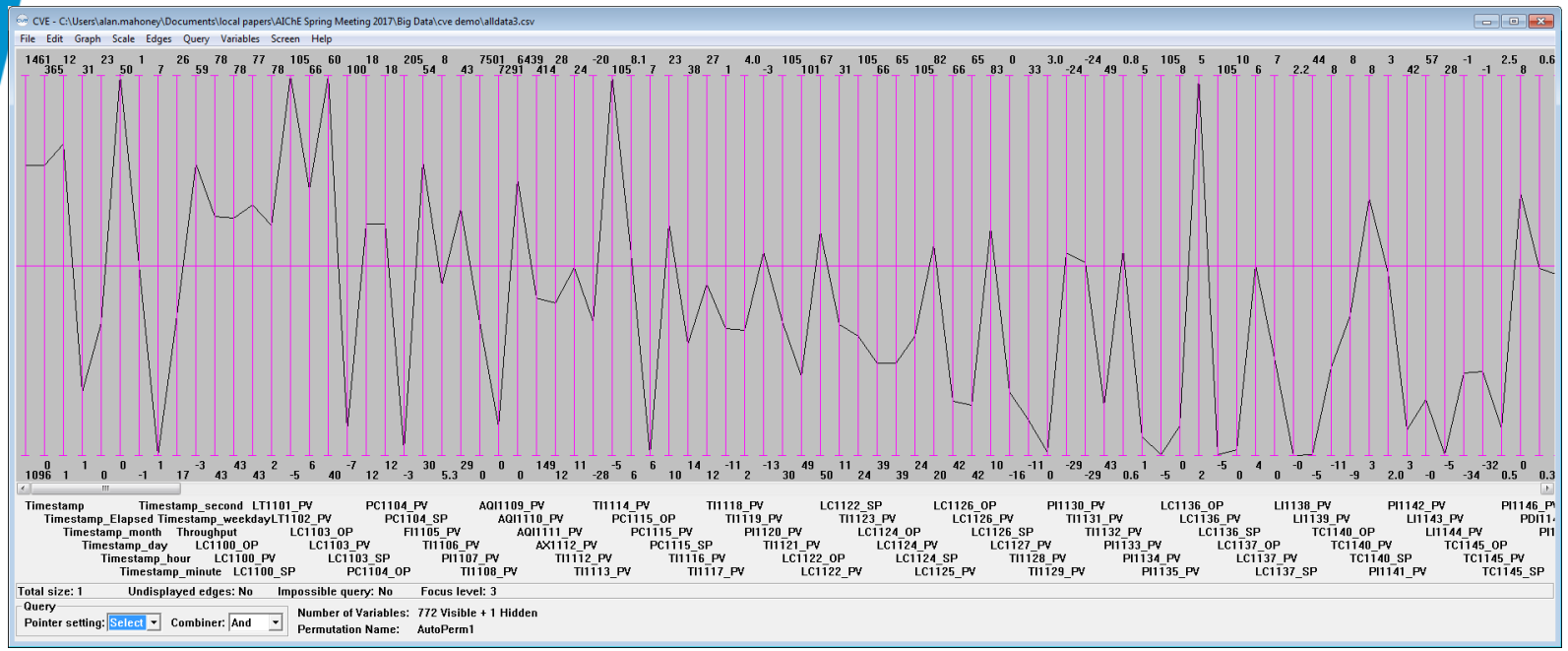
770 variables

Snapshots every 10 minutes

1 year

40 million individual measurements

Parallel Plot, One Row



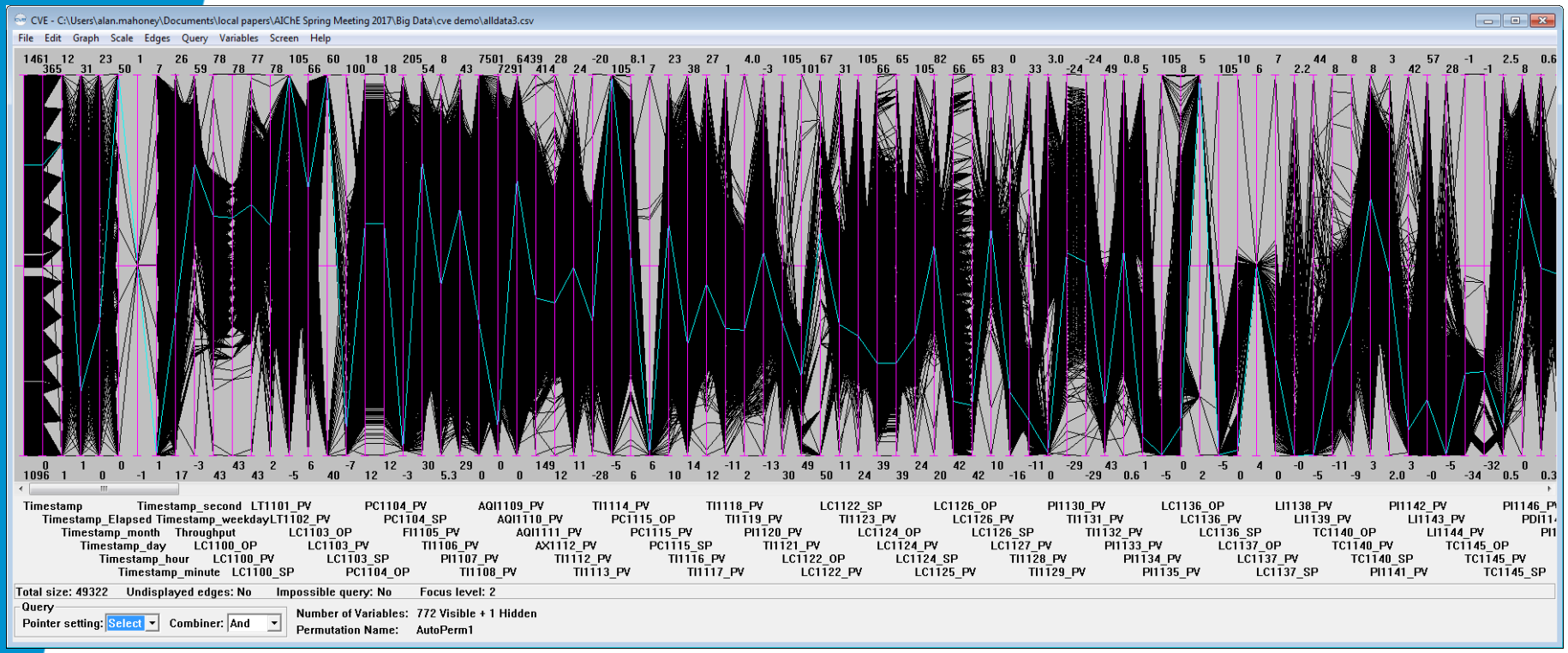
77 variables on this screen

Axes are parallel rather than perpendicular

Process snapshot of a single time

Line connects process conditions across all three units

Full Dataset



Each jagged line still represents one point in time

Links process causes and performance results

Line patterns and density capture process behaviour

Have already filtered: shutdown, events, process-quality time offset

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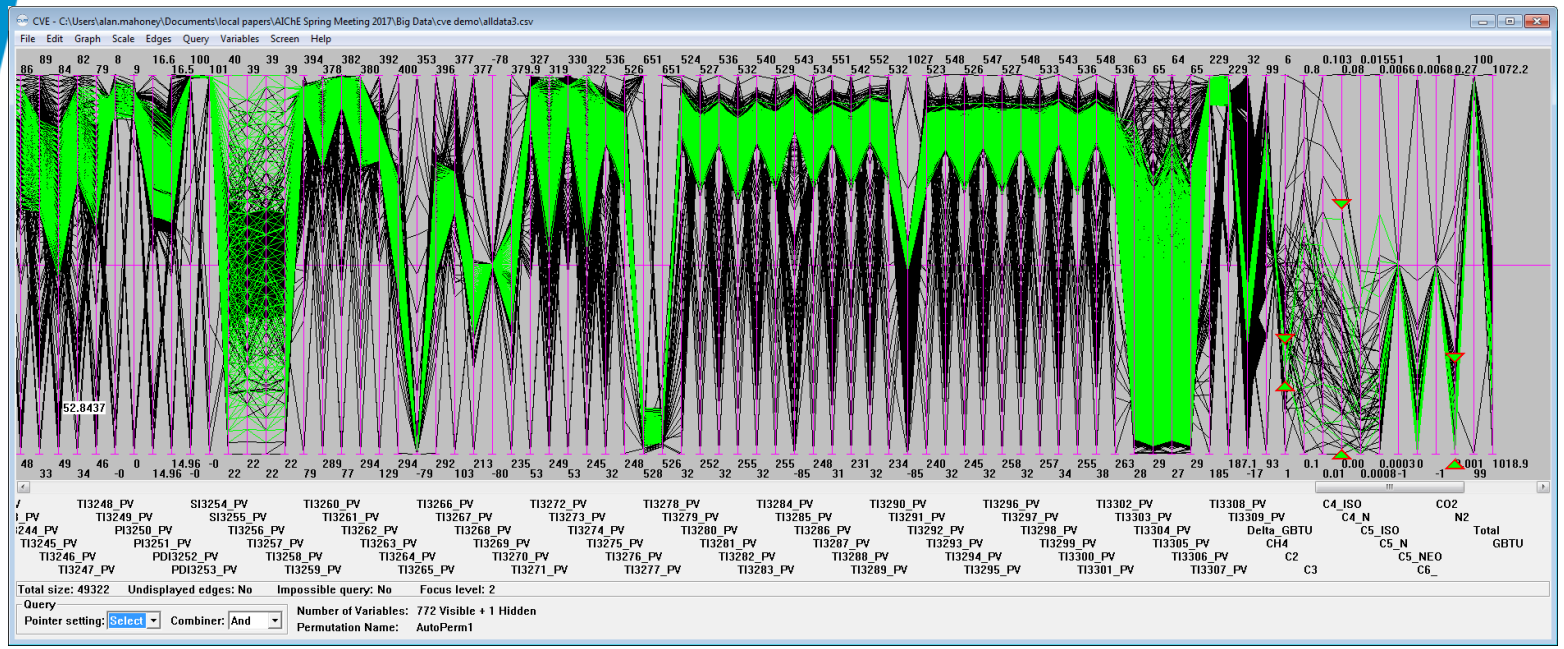
Target Operating Envelope



Best operation:

- Ideal product compositions
- Yield
- Best energy usage
- Complex combinations

Clearly identify

- where we should
- where we do but shouldn't operate

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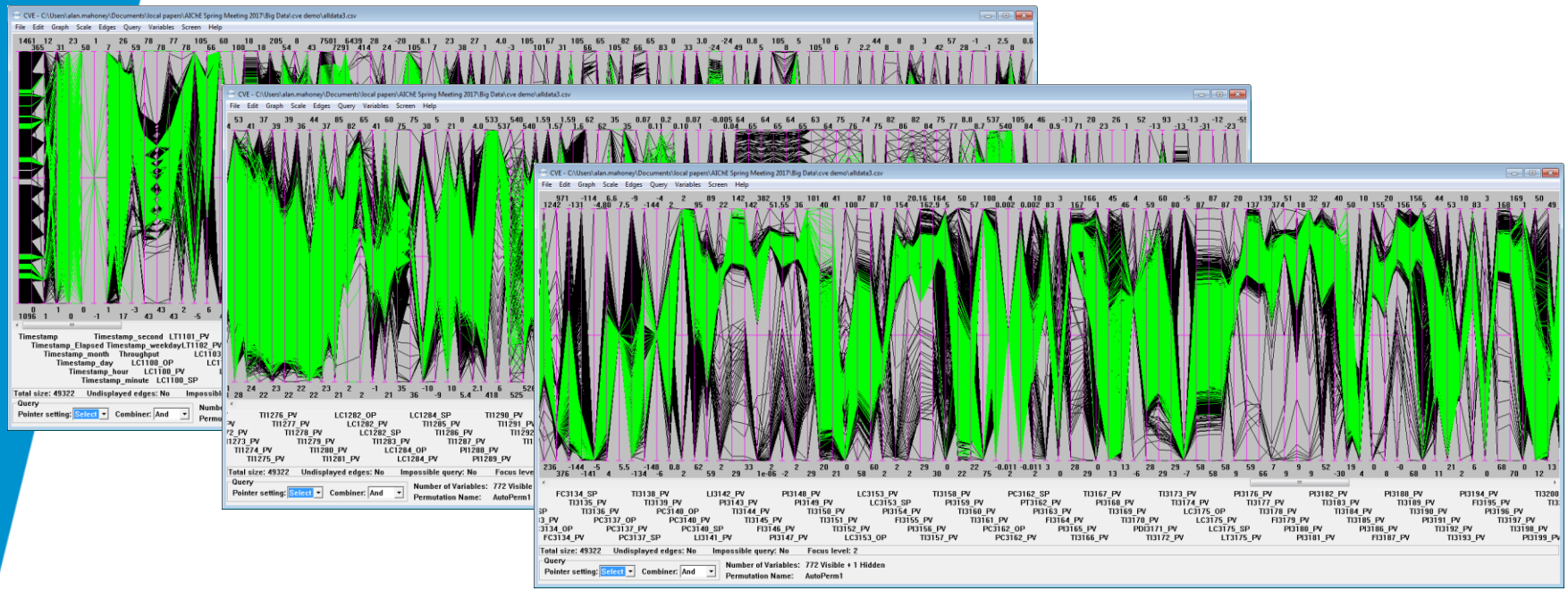
Quality Across Three Units

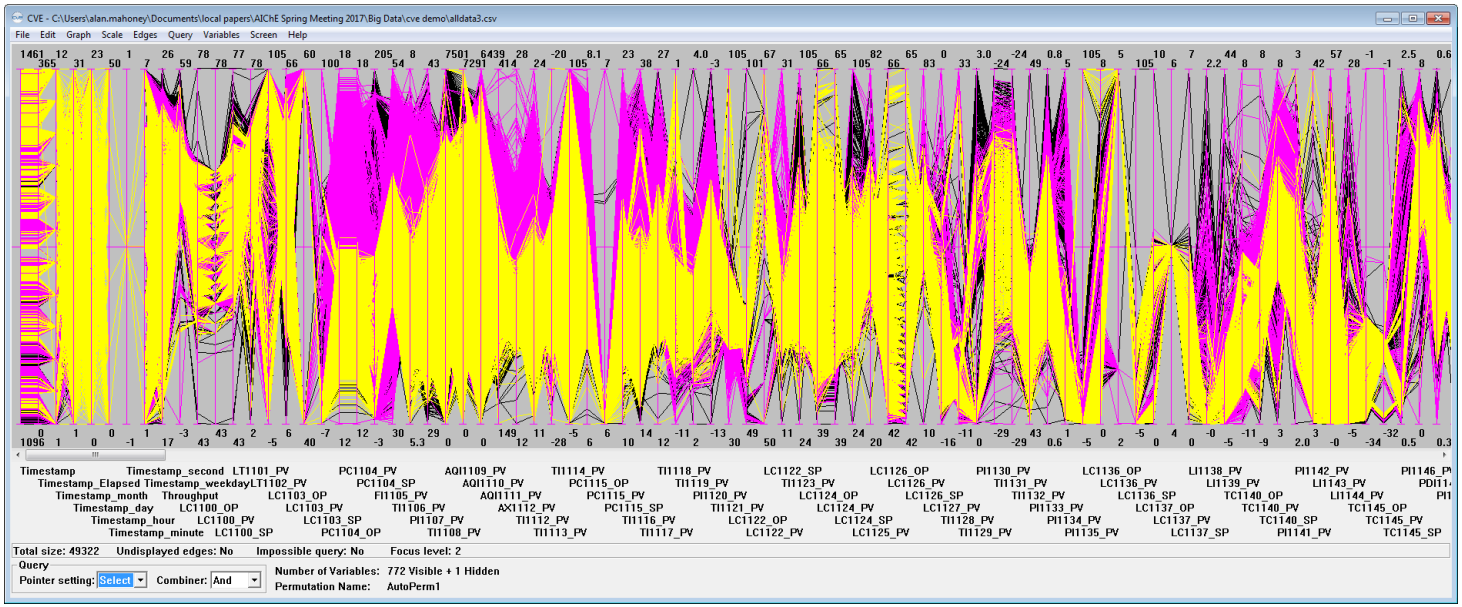


Envelope of Quality Operation visible across entire process

Variables in all three envelopes contribute to hitting quality targets

Possible to see and focus on key operating variables and ranges

Comparing Operations

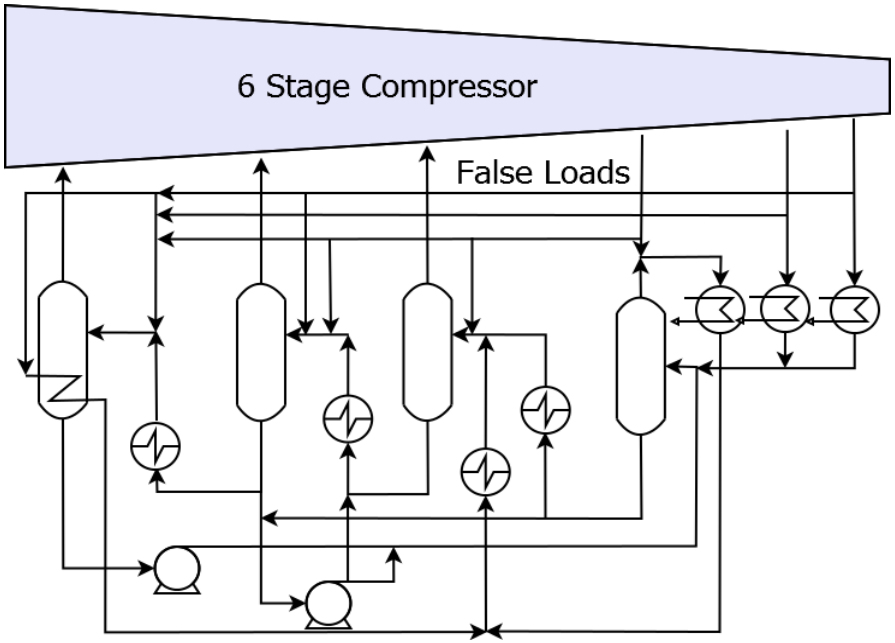


Impacts go through process: all units

Can see which variables and operations downstream are affected

Visually obvious differences

Event Prediction: Compressor Surge

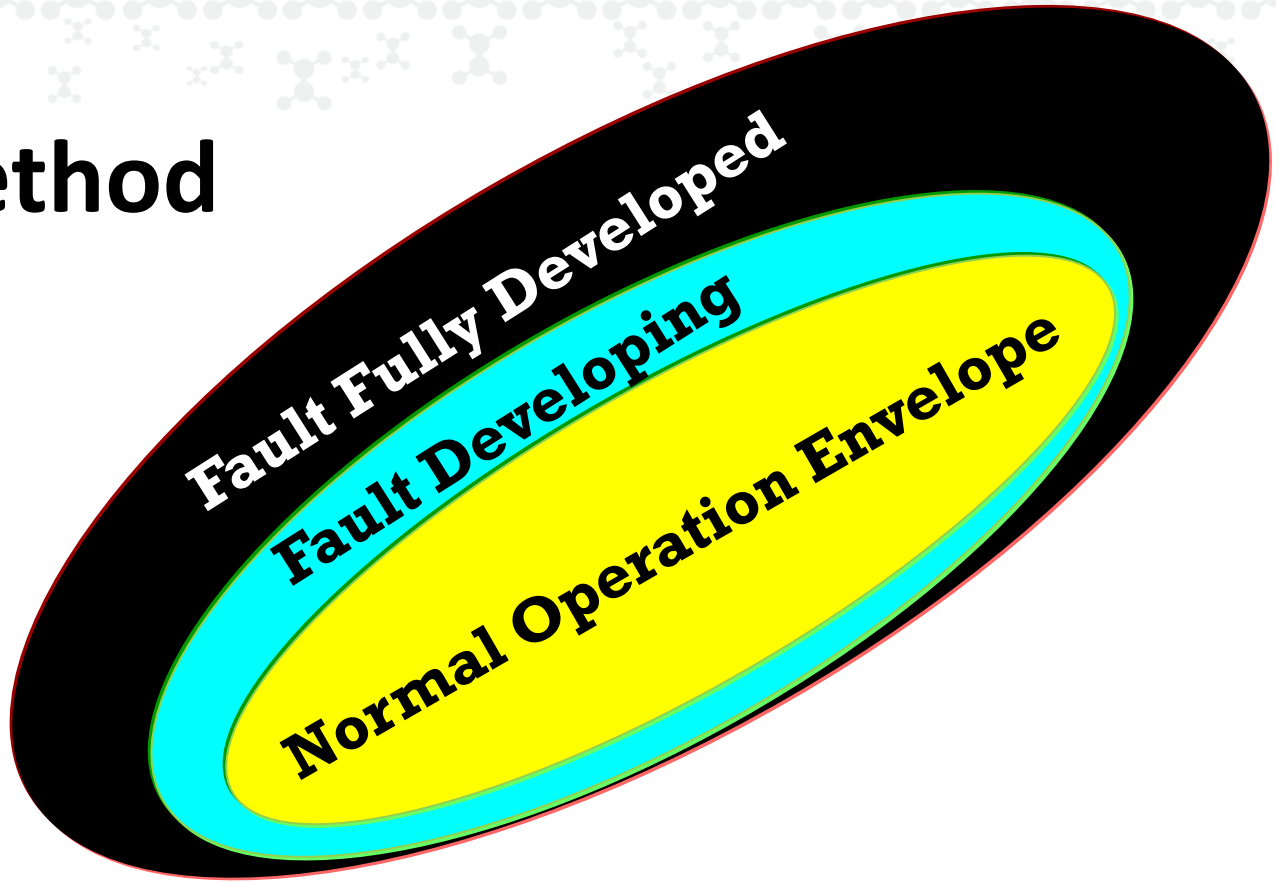


Ethylene refrigeration system

Long settling time because of interaction with the process

Avoid conditions where surge is likely

Method



Create an envelope from yellow past operation excluding the fault to be predicted

Avoid entering the fault condition black space

Violations of the envelope in real-time increase in the turquoise space when approaching the fault condition

Operations model, need warning times of many minutes so operator can act

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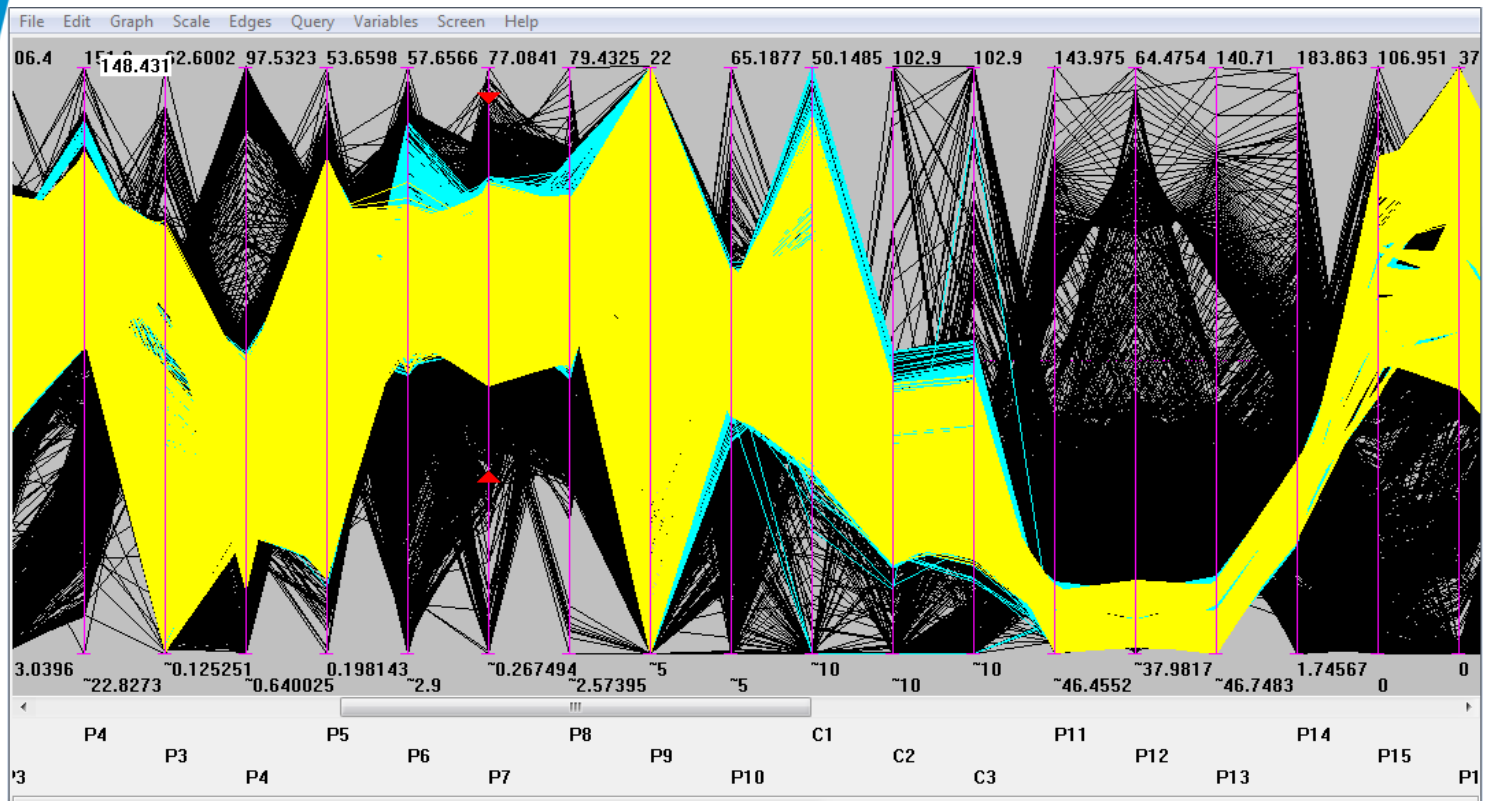
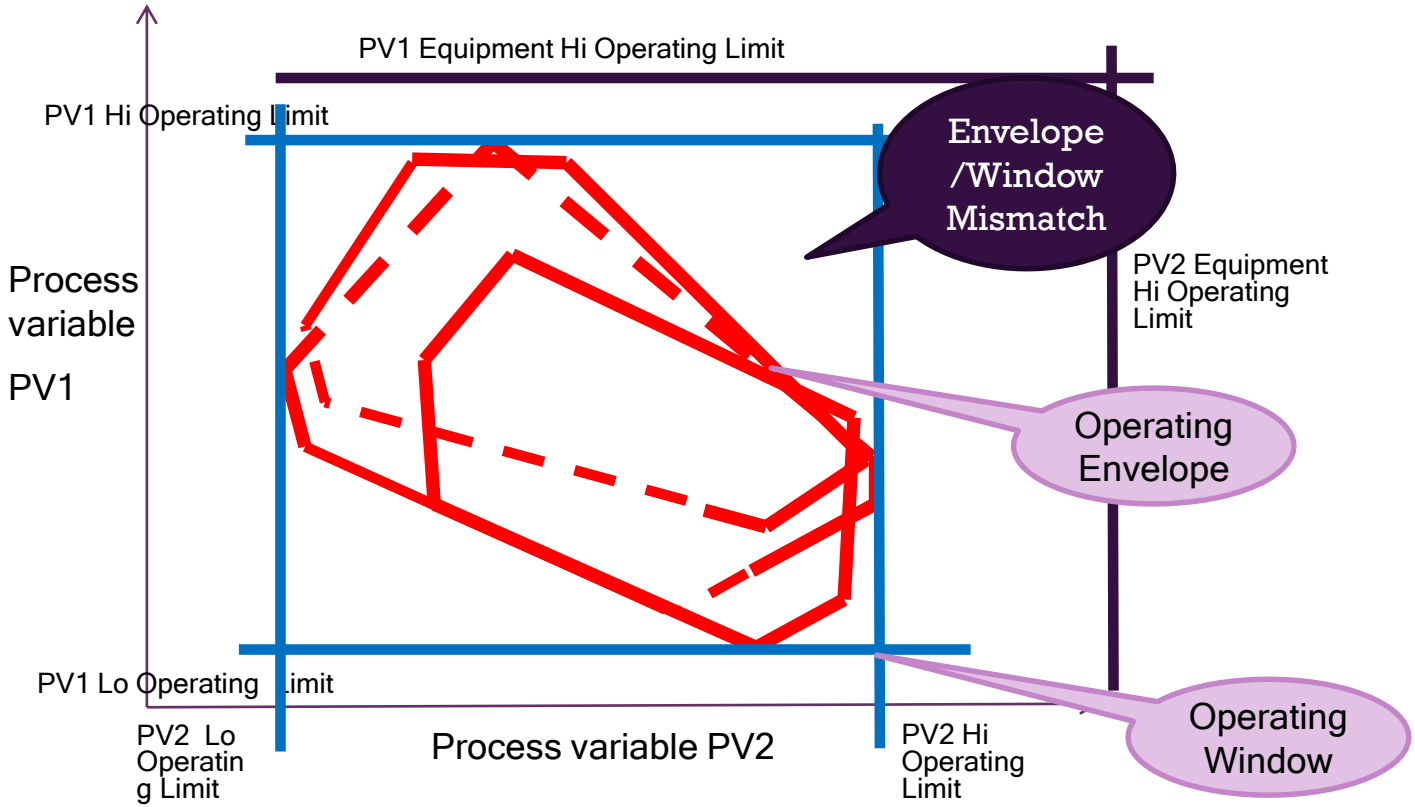
Fault Free Envelope



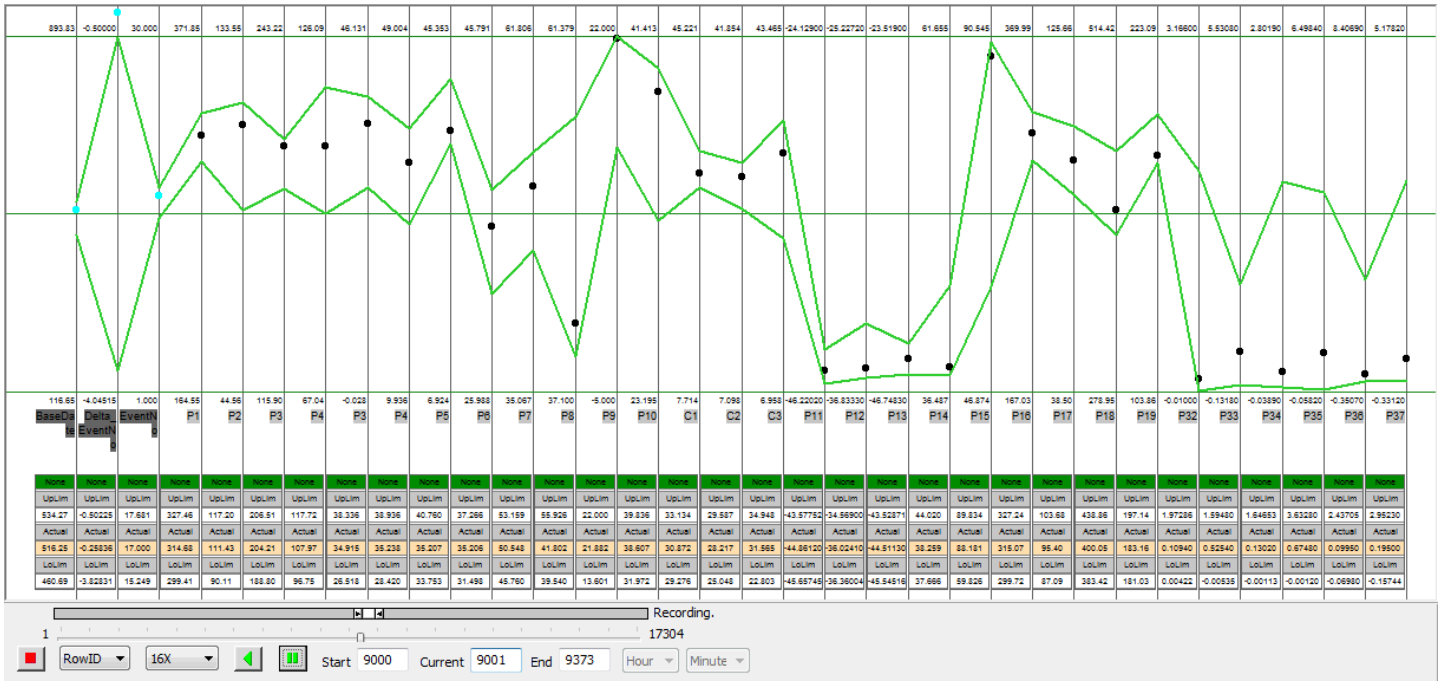
Model lies within suspicious data

Single variable excursions provide little warning

Operating Envelopes



Event Anticipation



Single event

Alerts begin 2 hours before event

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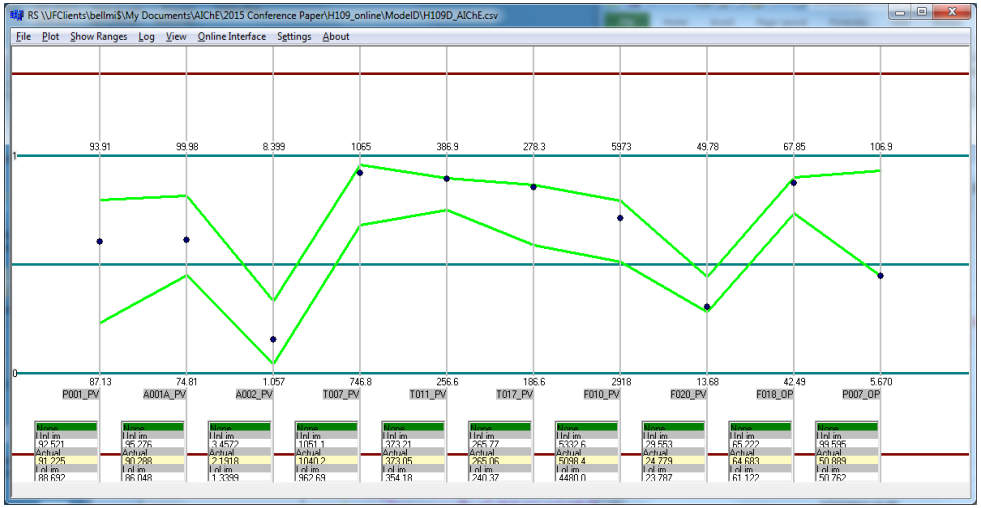
Ethylene Furnace Example

Ethylene Furnace Example

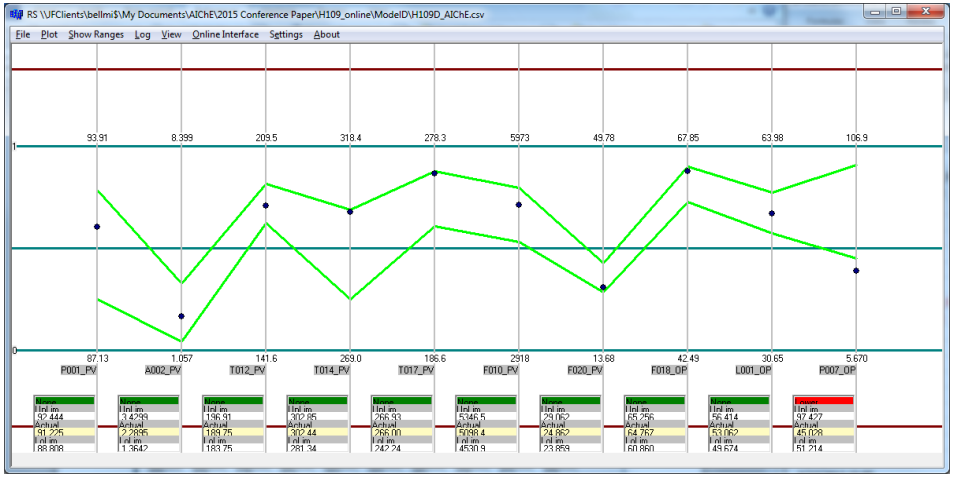
Furnace Historical Event – 2 ½ days before event - Normal



Reproduced courtesy of the author from "A Novel Approach to the Event Prediction and Mitigation Problem in an ethylene plant", Bell, M., Paper 098D, Proceedings of the AIChE Spring Conference 2015

Ethylene Furnace Example

Furnace Historical Event – 2 days 11 hours before event – Alert rings in – Small deviation from normal



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Ethylene Furnace Example

Furnace Historical Event – 1 Day before event – Alert continues - Large deviation from normal

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Ethylene Furnace Example

Furnace Historical Event – 2 mins before event – 3 Alerts

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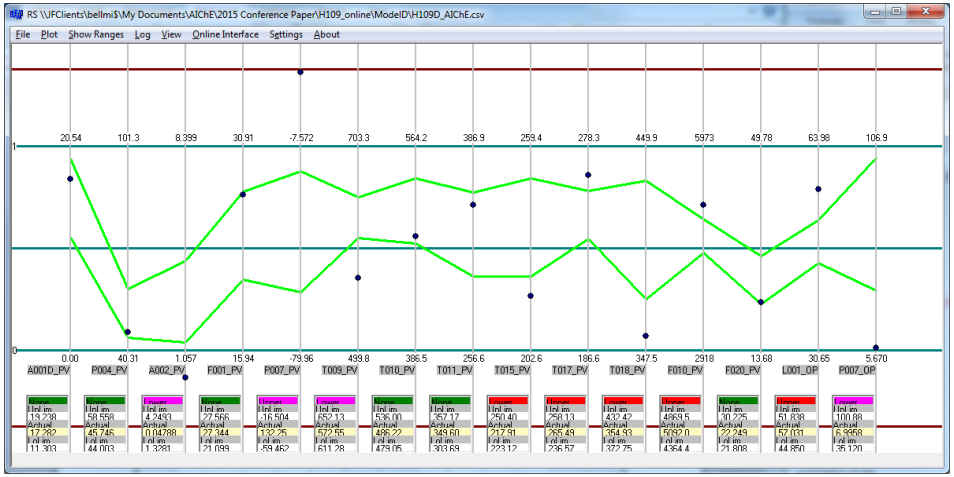
Ethylene Furnace Example

H109 Historical Event – Event is occurring – Multiple Alerts as operator is bringing furnace down



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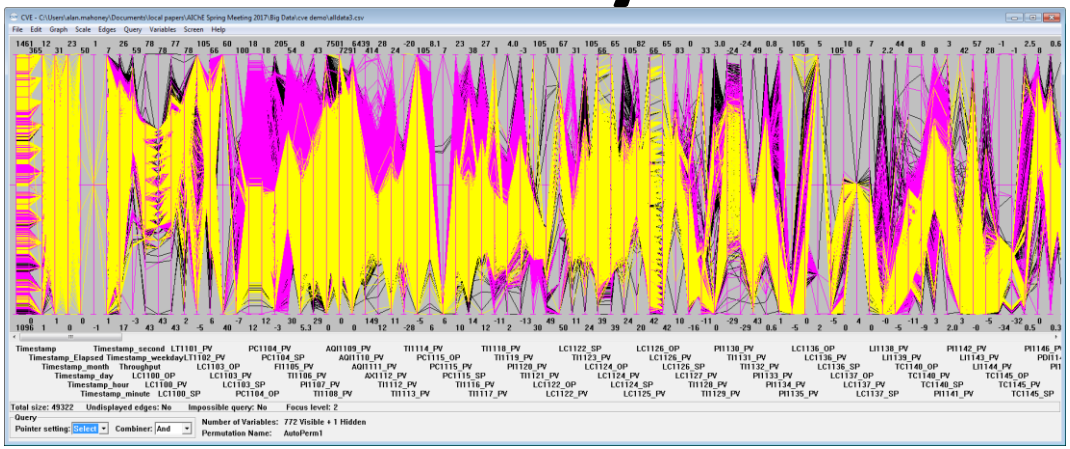
GPC Summary



Process experts can visually interrogate hundreds of variables at once

Operating envelopes for process optimization, energy minimization, stable operation

Potential for real-time process monitoring

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Questions