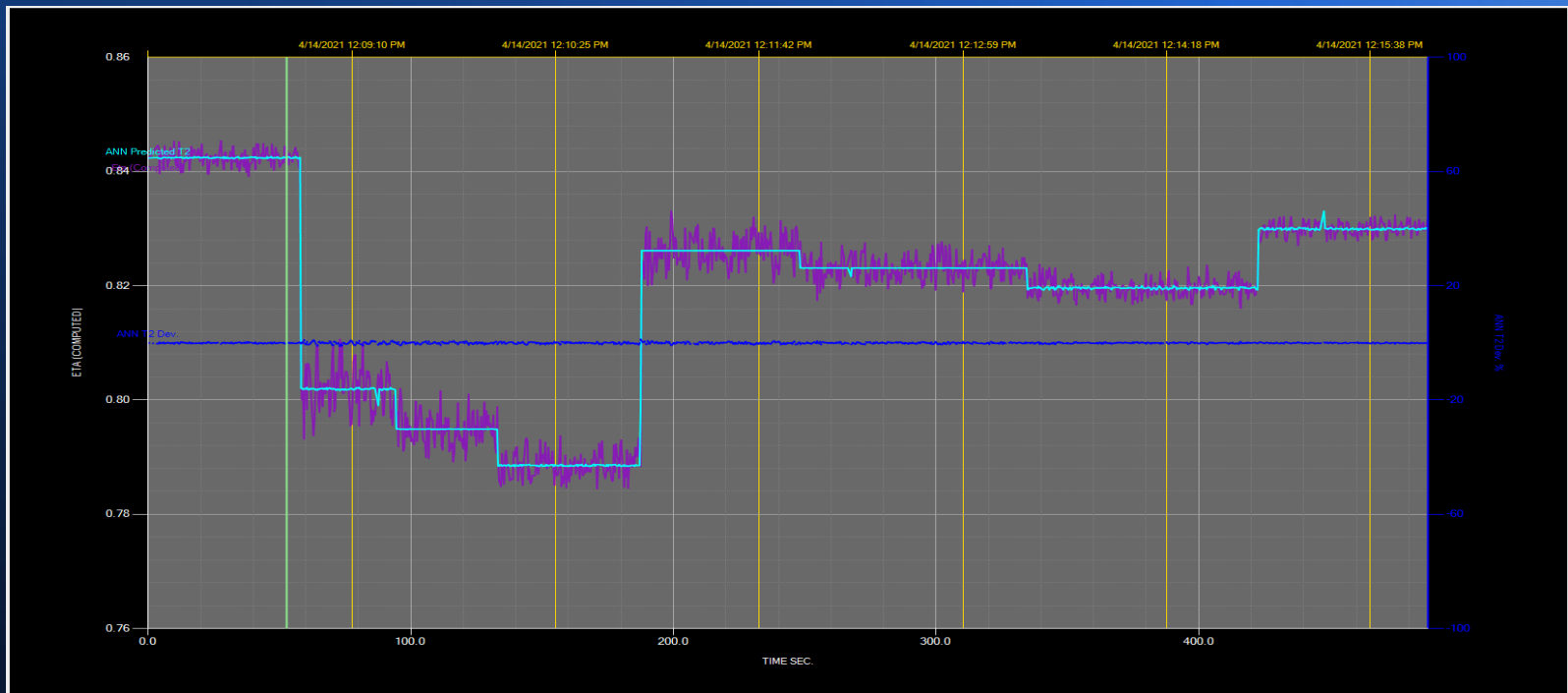
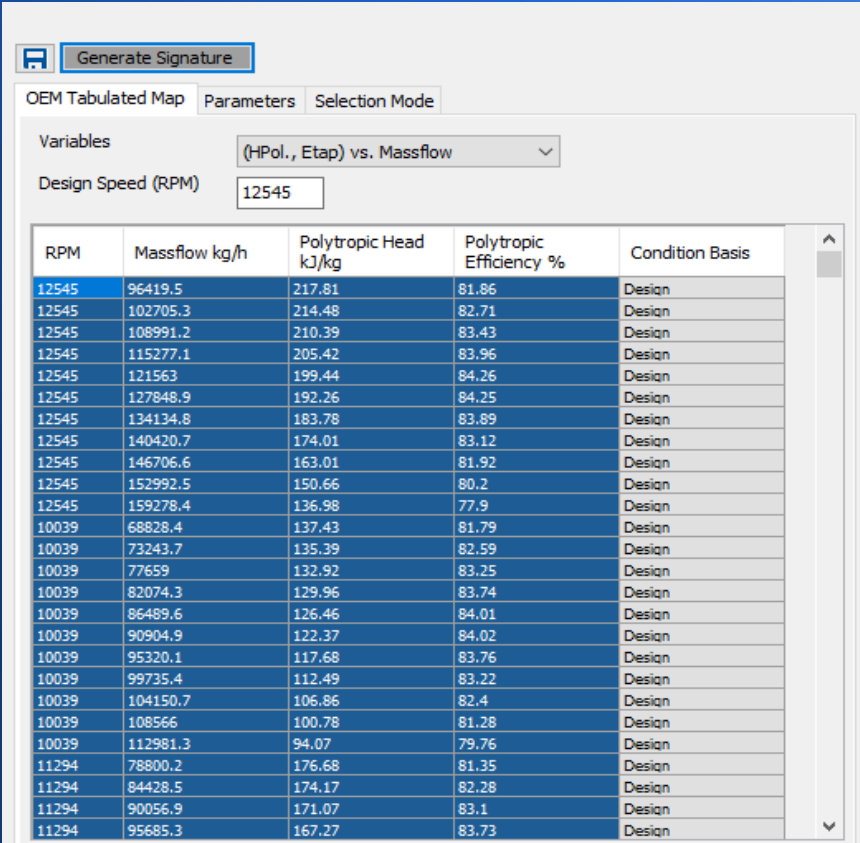


Ctrend Software for Centrifugal Compressor Performance Monitoring



Import Compressor Map

- Copy/Paste Reference Map data from Excel to CTrend
- Configure compressor data
- Add operating cases
- Generate signature



Generate Signature

OEM Tabulated Map Parameters Selection Mode

Variables (HPol., Etap) vs. Massflow

Design Speed (RPM) 12545

RPM	Massflow kg/h	Polytropic Head kJ/kg	Polytropic Efficiency %	Condition Basis
12545	96419.5	217.81	81.86	Design
12545	102705.3	214.48	82.71	Design
12545	108991.2	210.39	83.43	Design
12545	115277.1	205.42	83.96	Design
12545	121563	199.44	84.26	Design
12545	127848.9	192.26	84.25	Design
12545	134134.8	183.78	83.89	Design
12545	140420.7	174.01	83.12	Design
12545	146706.6	163.01	81.92	Design
12545	152992.5	150.66	80.2	Design
12545	159278.4	136.98	77.9	Design
10039	68828.4	137.43	81.79	Design
10039	73243.7	135.39	82.59	Design
10039	77659	132.92	83.25	Design
10039	82074.3	129.96	83.74	Design
10039	86489.6	126.46	84.01	Design
10039	90904.9	122.37	84.02	Design
10039	95320.1	117.68	83.76	Design
10039	99735.4	112.49	83.22	Design
10039	104150.7	106.86	82.4	Design
10039	108566	100.78	81.28	Design
10039	112981.3	94.07	79.76	Design
11294	78800.2	176.68	81.35	Design
11294	84428.5	174.17	82.28	Design
11294	90056.9	171.07	83.1	Design
11294	95685.3	167.27	83.73	Design

Configure Modbus & Instrumentation Setup

- Configure Modbus communication parameters
- Configure Flow Transmitter data (ISO 5167), process variable units
- Configure I/O's tags, registers, calibration ranges

Protocol
 Format: WORD16+
 Server Unit ID: 1
 First Register: 300001
 Timeout (Second):

TCP/IP
 Server IP Address: 127.0.0.001
 Server Port: 502

RTU/ASCII
 Parity: NONE
 Port (COM): 1
 Baud Rate: 9600
 Stop Bits: 1

Scanning Settings
 Screen Buffer Size (No. Sample): 100
 Scan Delay (T1) (>= 1 sec): 0.01 Second

Signal Averaging
 No. Sample: 1
 Scan Interval (mSecond): 100

Filter (ModRSsim2 Simulator)
 Interval (mSecond): 100
 Constant: 1E-1

Apply Cancel

FMD Location: Suction

FMD Design Type: 1- Orifice (Corner taps)

Alpha PE (1/K): 0

Alpha P (1/K): 0

Ref. Temperature (K): 293.15

Absolute Viscosity (cP): 0 *Automatic calc. if =0*

Pipe Inside D (mm): 450

Device Throat d (mm): 300

Solver Settings
 Gussed Reynolds Nr. (Re_G): 1e5
 Search Upper Value (x Re_G): 0.5
 Search Lower Value (xRe_G): 2

Calculation Override
 Geometry Coefficient A_w: *Override if A_w <> 0*

Apply Ok

Analog Inputs Plot Setup Log Data

Units
 Pressure: MPa-a Temperature: K Flow: kg/h

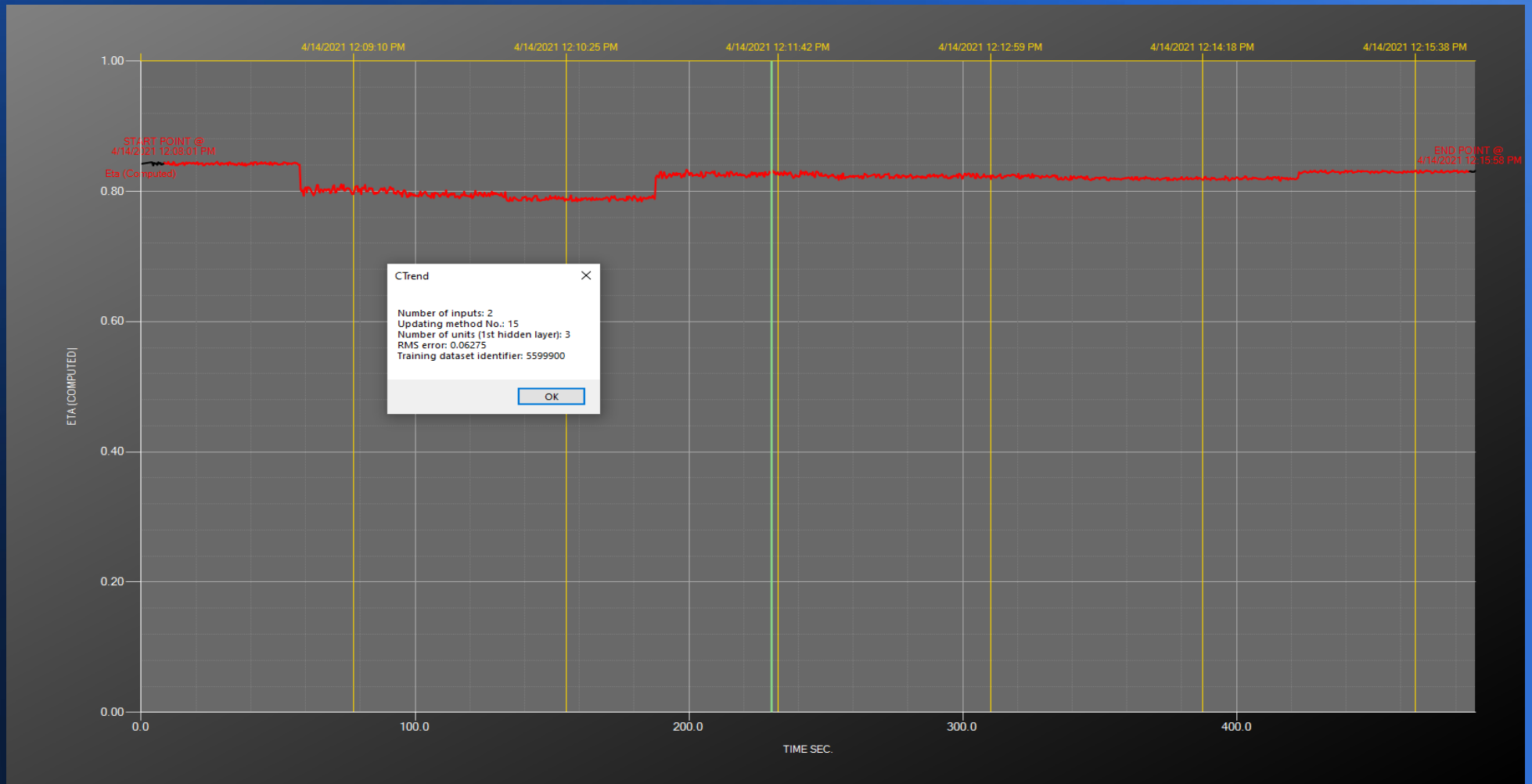
ID	Tag	Description	Address	Data Low	Data High	EU Low	EU High	PS
1		FLOW	300001	0	65535	0	150000	1
2		SUCTION PRESSURE	300002	0	65535	0	7.902	1
3		SUCTION TEMPERATURE	300003	0	65535	122.4	496	1
4		DISCHARGE PRESSURE	300004	0	65535	0	18.4580	1
5		DISCHARGE TEMPERATURE	300005	0	65535	286.8	478.8	1
6		SHAFT SPEED	300006	0	65535	0	15930	1

PS	Mixture	Map Basis	Speed Ratio%	Threshold PR.Ratio%	Threshold Efficiency%	Threshold Power%
1	Design	Design	100	0.1	0.1	0.1

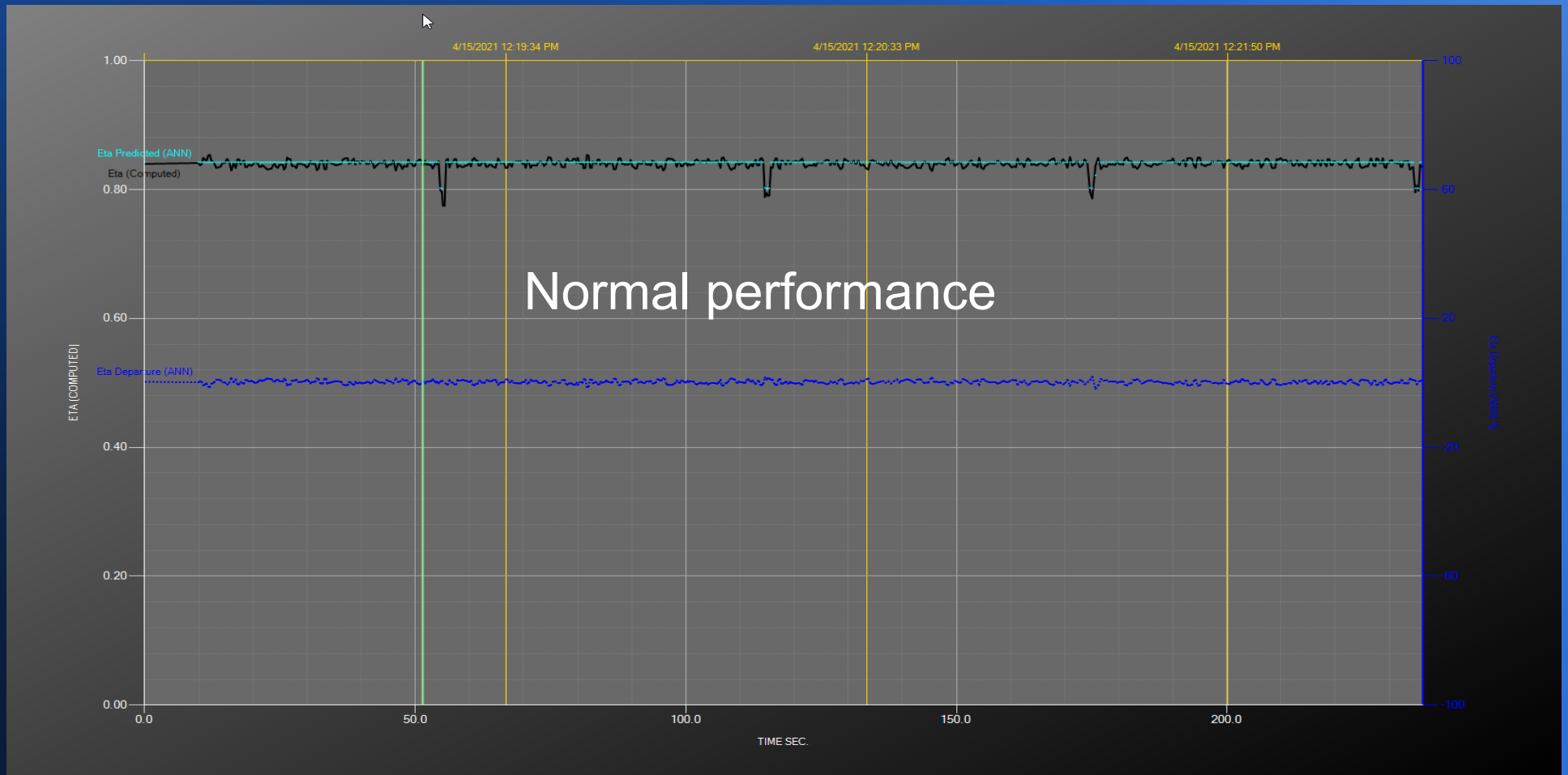
Baseline Performance Model Setup

- Train the ANN on historian data (baseline model for performance)
- Track down current performance departure from baseline
- Use baseline model to detect abnormal condition of operation and drop of performance and perform further investigation / maintenance action
- Apply baseline model on off-design points (for example on high flow and low efficiency region, drift of molecular weight) which are otherwise complicated to scrutinize in absence of benchmark

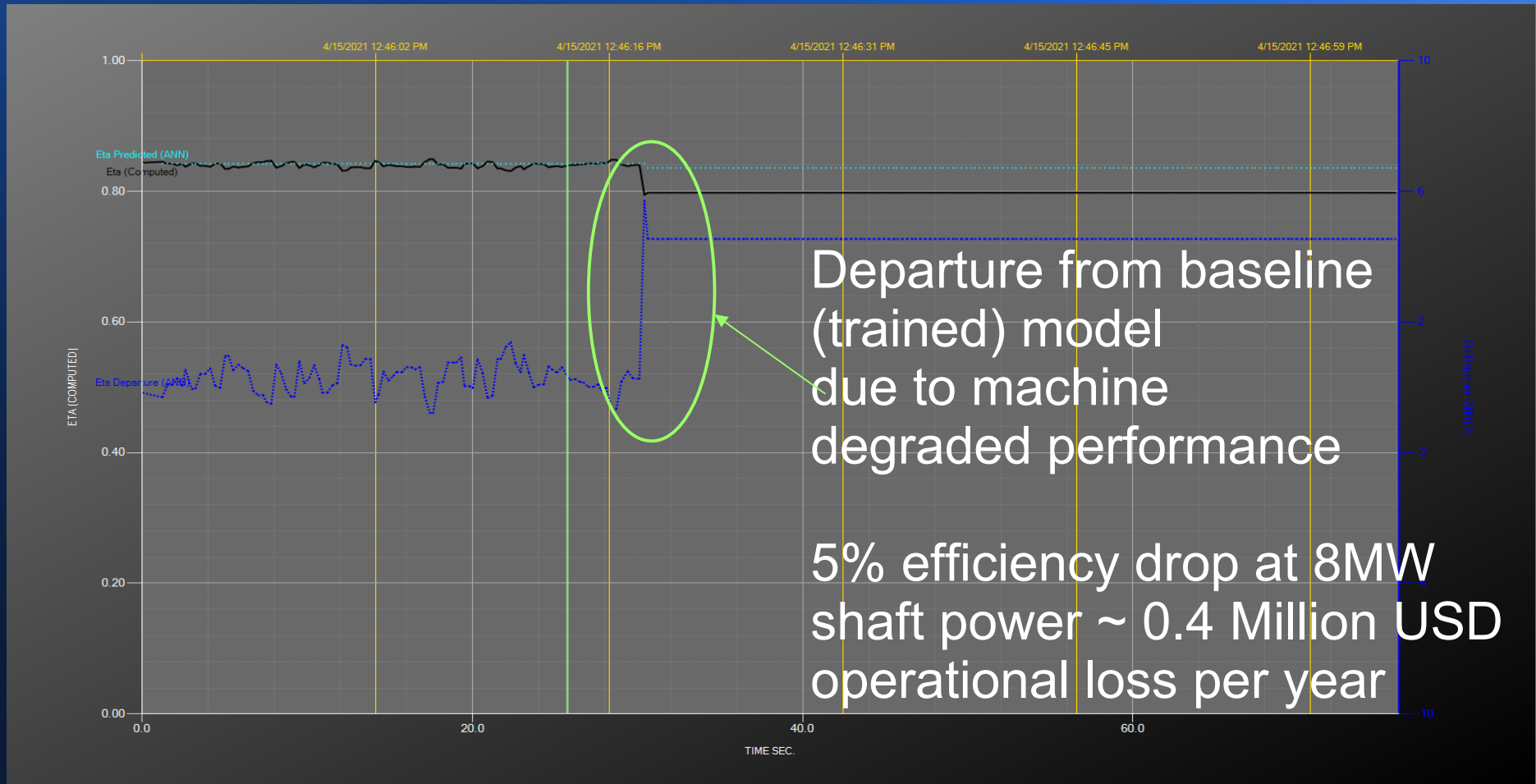
Baseline Performance Model Setup



Track Performance Drop



Track Performance Drop



Economic Impact

- On a 8 MW power rated motor driven gas booster centrifugal compressor, a 5% drop in compressor performance may result in
 - ~0.4 Million USD/year loss in operating costs (0.10 USD / kWh basis)
 - Throughput decrease (for example, machine operating at maximum speed) limiting production
 - Increase of CO₂ emissions ~1500 ton/year (453 gCO₂ / kWh basis)
 - Further costs associated to emitted CO₂ depending on country (e.g., ETS)

⇒ Sources / Further Information:

⇒ <https://www.setmach.tech/energy-cost-emission>

https://carbonpricingdashboard.worldbank.org/map_data

⇒ [https://www.eea.europa.eu/data-and-maps/data/co₂-intensity-of-electricity-generation](https://www.eea.europa.eu/data-and-maps/data/co2-intensity-of-electricity-generation)

Summary of Features

- DCS/Modbus data acquisition capability enabling live performance computation using highly accurate equation of state
- Scan rates down to 300 ms which could be useful for averaging sample data and improving signal to noise ratio
- Investigation of off-design operating conditions
- Artificial Neural Network machine learning predictor for the analysis of performance and departure from baseline model (trained)
- Map-based predictions available (extended mode)
- Historian analysis allowing retrieving of log data files (timestamps) and merging of time series
- Investigative tool with comprehensive facilities for supporting the execution of diagnostics and predictive maintenance