An Advanced Analytic Solution for ESP Monitoring in Upstream Oil Production

Session ID: 5-1964

TUNE IN

EMERSON GLOBAL USERS EXCHANGE

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Thank you!

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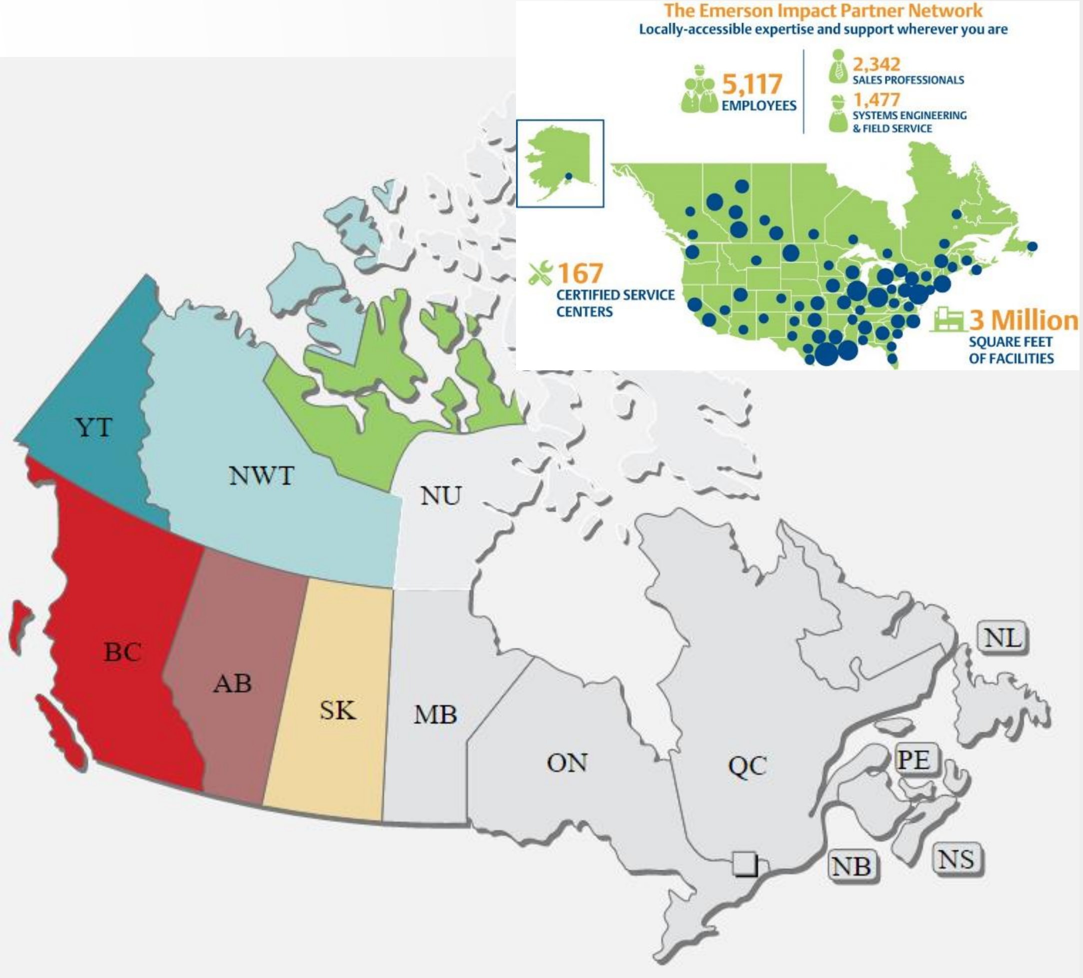


RESEARCH COLLABORATION

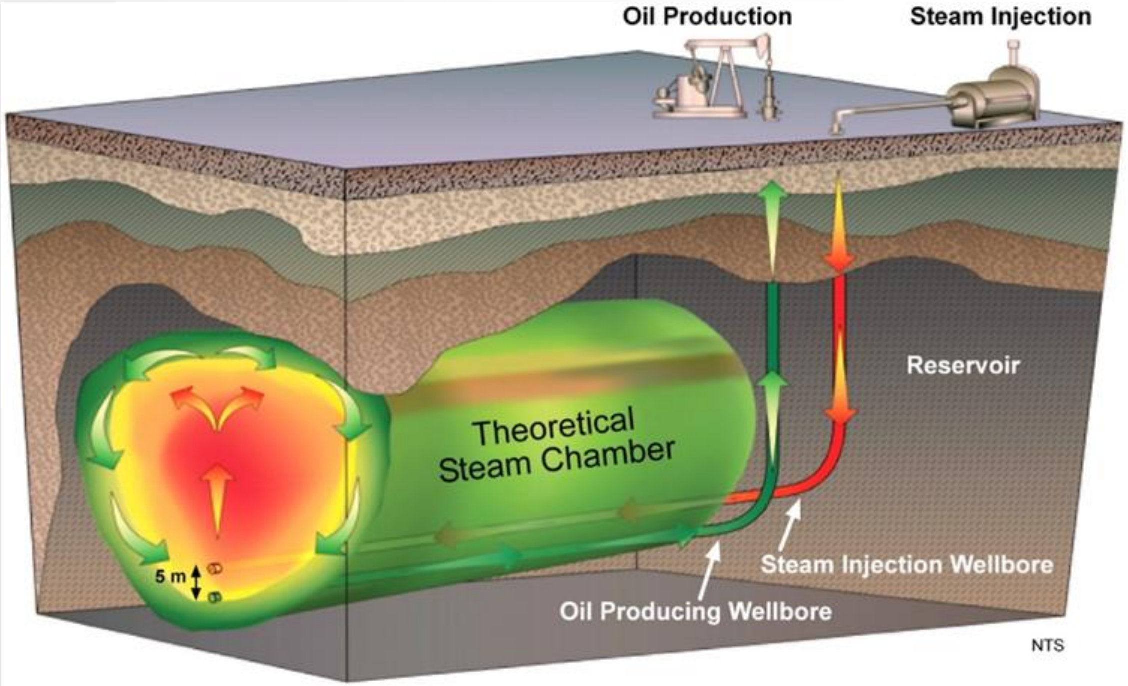
- NSERC Senior Industrial Research Chair in Control of Oil Sands Processes
  - Chair holder: Biao Huang, Ph. D., P. Eng., Professor, Dept. Chemical and Materials Engineering, University of Alberta
  - Industrial Partners

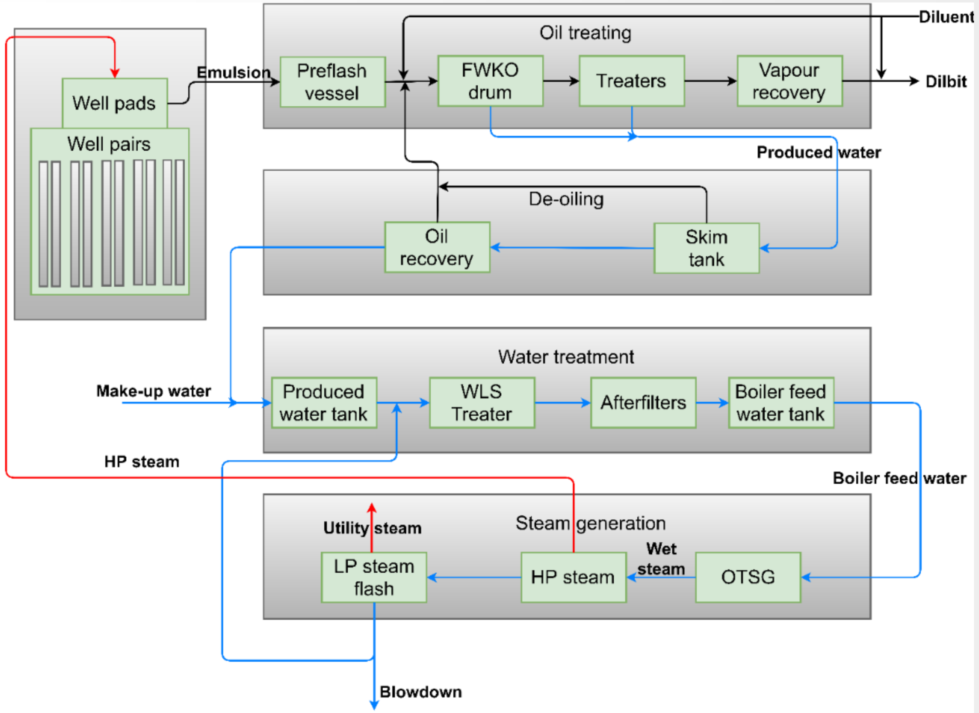
AGENDA

- Introduction
  - Process: Steam assisted gravity drainage process
  - Equipment: Electric submersible pumps (ESPs)
  - ESP reliability issues
- Monitoring Solutions
  - Monitoring based on performance curves
  - Data-driven models for failure prediction
  - Pattern recognition techniques
- Emerson’s Analytics Platform
- Business Results Achieved
- Summary

STEAM ASSISTED GRAVITY DRAINAGE (SAGD) WELLS

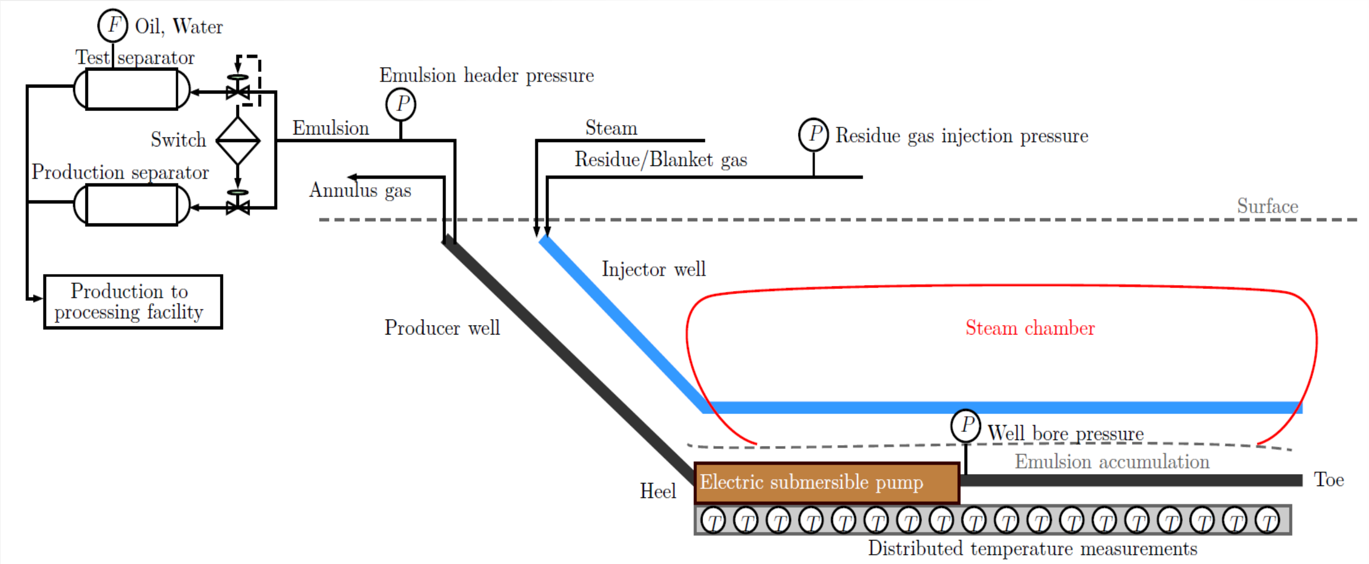
- Alberta's SAGD production capacity: ~ 1.28 million bbl./day
- Amount of steam injected per day: ~ 3.59 million bbl./day

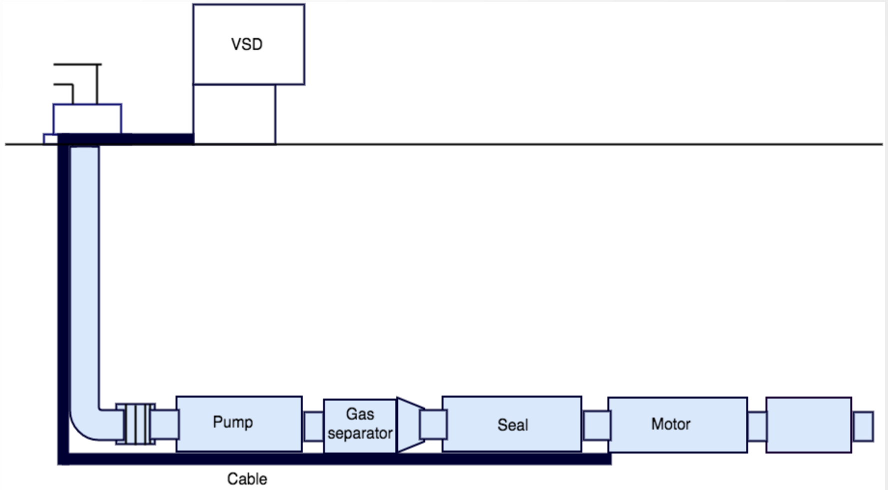




ELECTRIC SUBMERSIBLE PUMPS IN SAGD APPLICATION

- ESP run life in SAGD: 2 months to 3 years
- Workover and replacement in case of a failure costs half a million to a million dollars



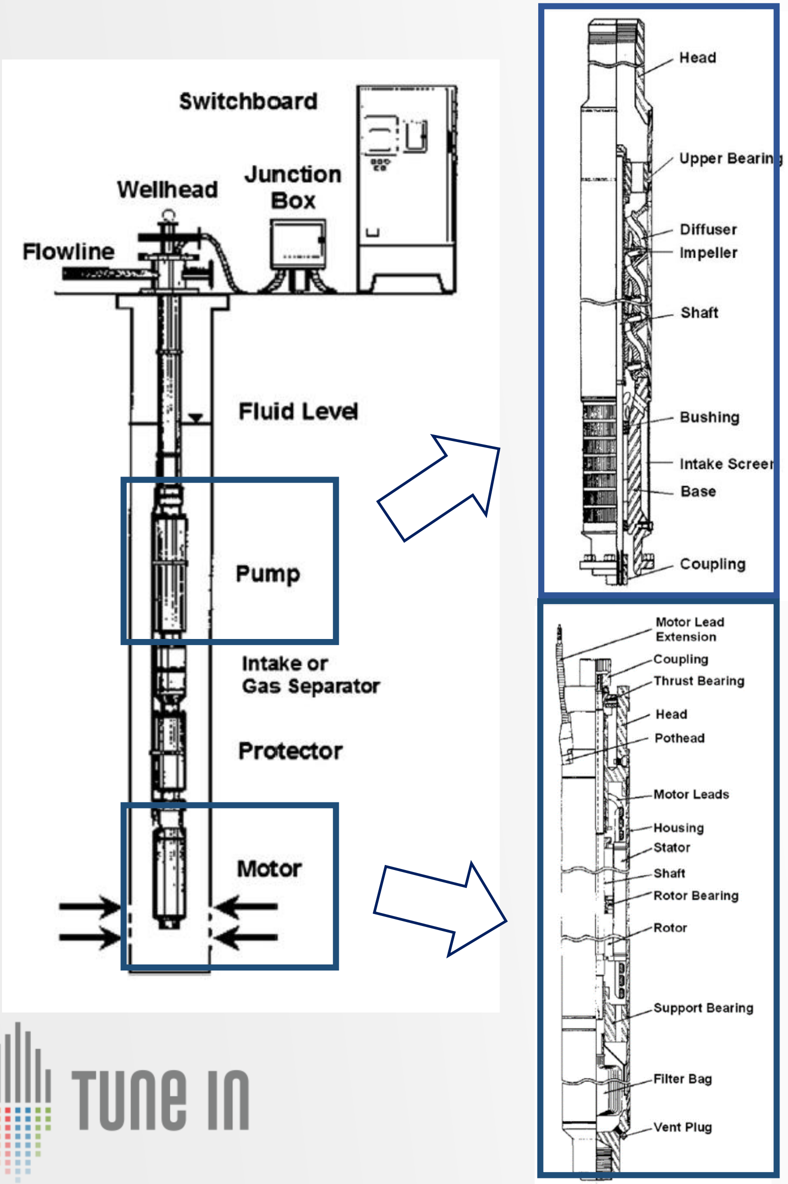


ELECTRIC SUBMERSIBLE PUMPS IN SAGD APPLICATION

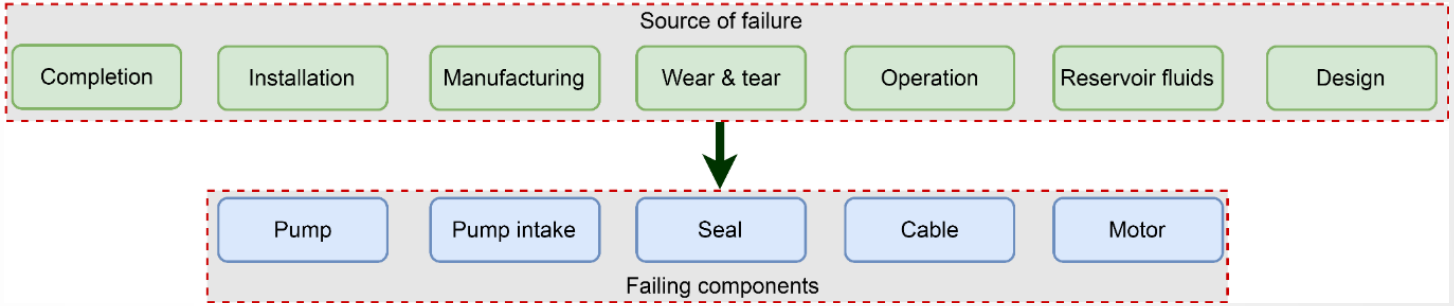
Facility	Production (bbl./day)	SOR	Number of Wells (Inj+Prod)	Steam (bbl./day)	ESP wells
AOC Hangingstone	12,000	4.66	46	55920	19
AOC Leismer	20,000	3.18	77	63600	42
PetroChina MacKay River	35,000	4.81	83	168350	6
CNRL Kirby South	40,000	2.74	108	109600	47
Cenovus Christina Lake	210,000	1.87	422	392700	229
Cenovus Foster Creek	180,000	2.67	543	480600	227
Nexen Long Lake	72,000	3.72	213	267840	109
Connacher Great Divide	20,000	4.34	89	86800	13
Conoco Surmont	150,000	3.04	355	456000	108
Devon Jackfish	105,000	2.37	336	248850	1
Husky Sunrise	60,000	4.25	124	255000	45
Husky Tucker Lake	30,000	3.49	179	104700	0
MEG Christina Lake	80,000	2.21	373	176800	149
OSUM Orion	10,000	3.59	50	35900	1
Pengrowth Lindbergh	12,500	3.13	60	39125	34
Suncor Firebag	203,000	2.63	373	533890	~106
Suncor MacKay River	38,000	3.1	208	117800	2
	Total Production	SOR Average	Number of well pairs	SOR (weighted average)	Number of ESP wells
	~1.3 (million bbl/day)	~3.28	~1820	~2.81	~1138

Data from https://www.oilsandsmagazine.com/projects/thermal-in-situ (as of September 2018)

ESP RELIABILITY ISSUES

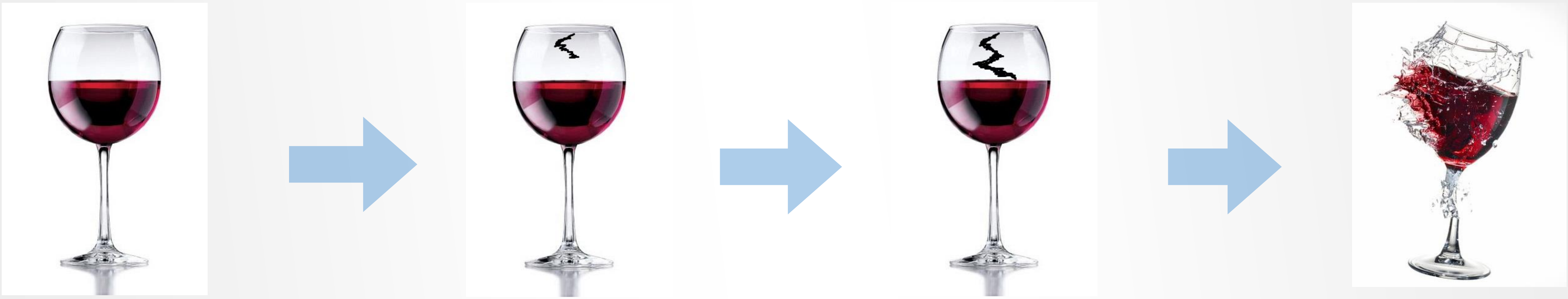


- Completion failures
  - Wellbore and liner damages
  - Sand control system failure, etc.
- Manufacturing
  - Material selection
  - Assembly
- Installation
  - Well cleanout
  - System assembly
- Operation
  - Poor operating procedure
  - Inadequate condition monitoring
- Reservoir fluids
  - Sanding
  - Gas &/steam breakthrough
- Design
  - Wrong selection of equipment
- Wear & Tear



EQUIPMENT MONITORING

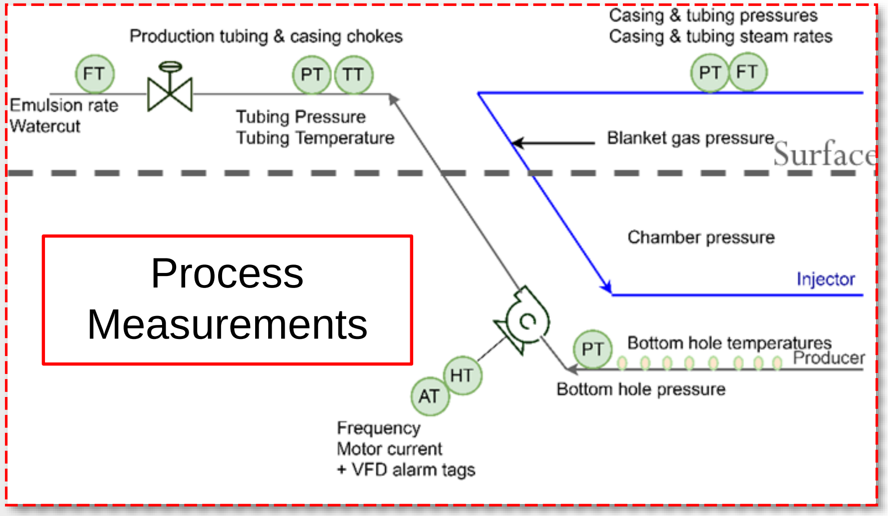
- **Fault detection:** Detect incipient fault that may lead to equipment failure
- **Fault diagnosis:** Identify the root cause, recommend/implement corrective measures, etc.
- **Fault prognostics:** Failure prediction, predict remaining useful life, etc.



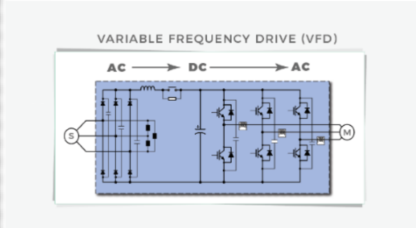
Healthy | Fault | Fault propagation | Failure

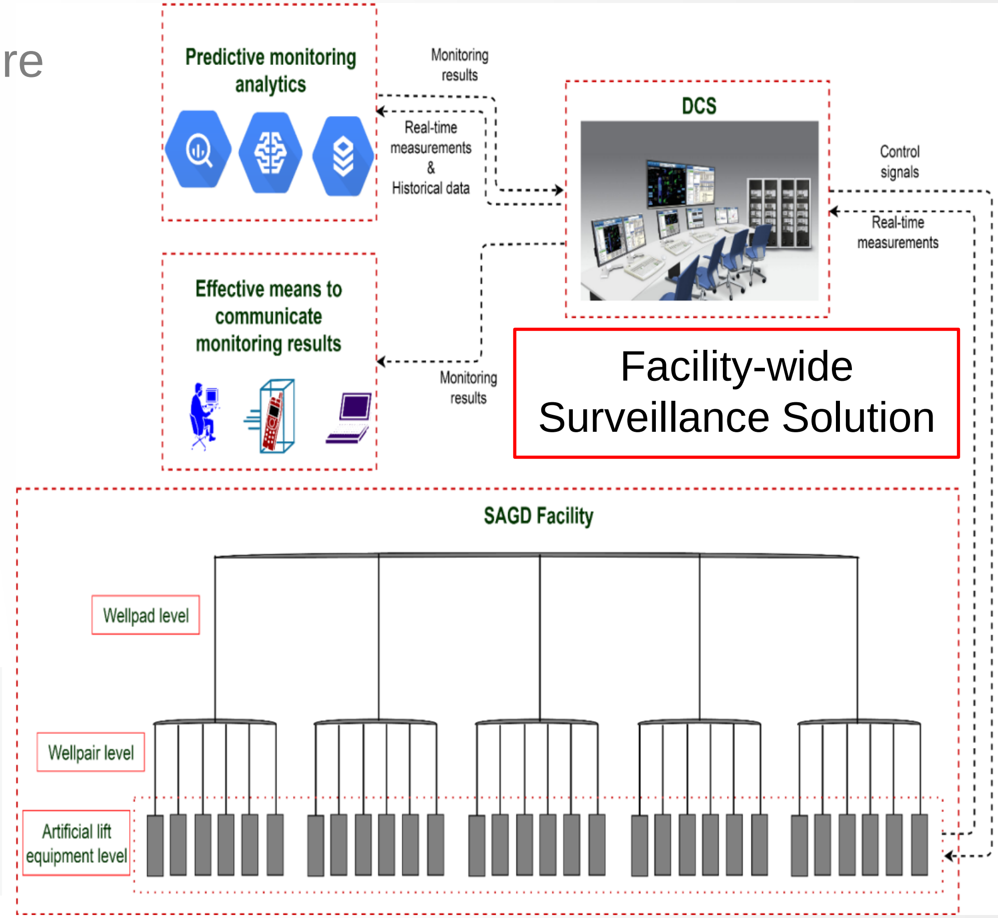
REQUIREMENTS OF AN ESP MONITORING SOLUTION

- Data-driven models from real-time measurements to monitor pump performance and predict failure
- Detect and diagnose conditions that will lead to pump failure
- Communicate actionable suggestions
- Facilitate decision making
- Closed-loop control



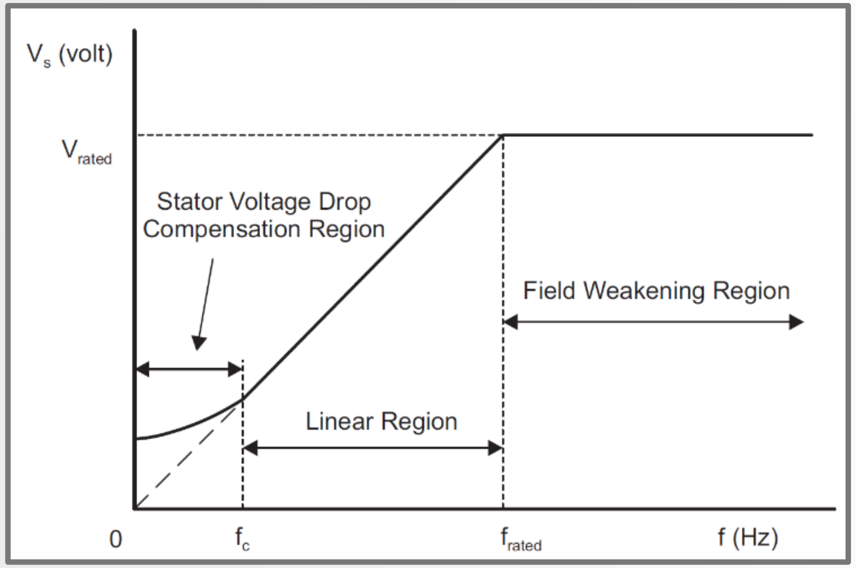
Drive data

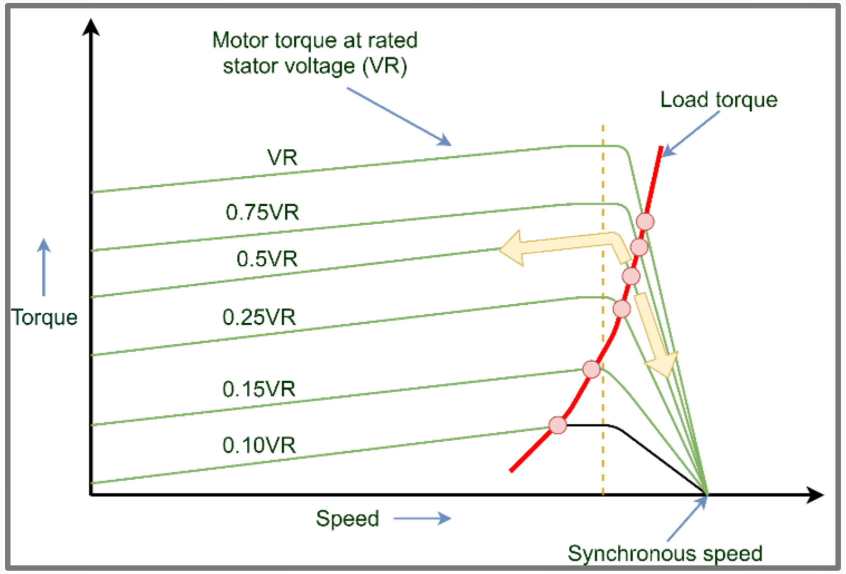


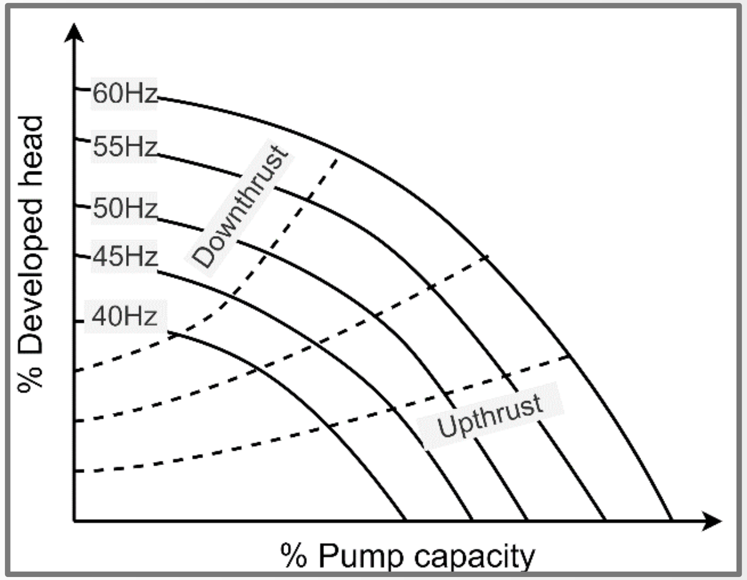


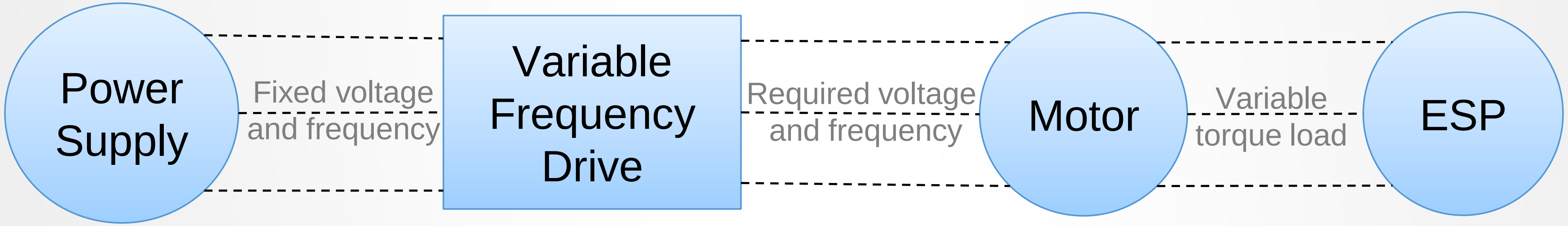
PERFORMANCE MONITORING ALGORITHMS

- Characteristic curves reconstructed using data-driven models
- Online operating conditions are compared against the characteristic curves





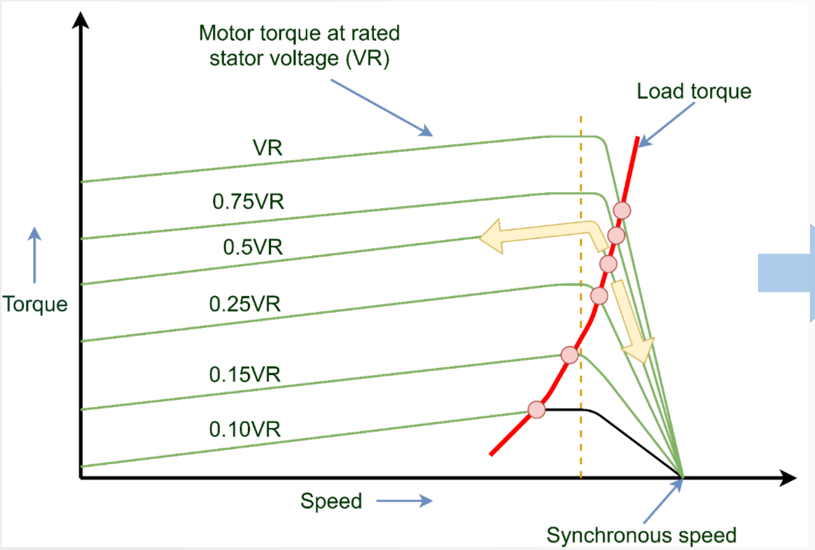




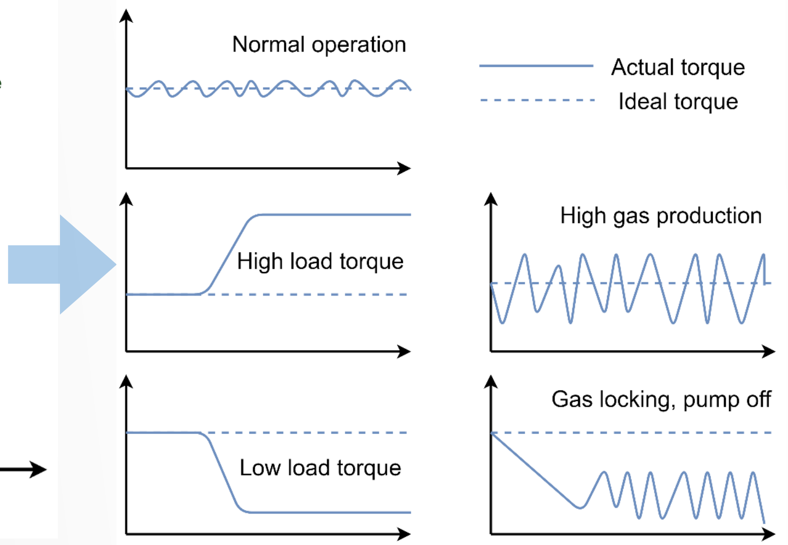
PERFORMANCE MONITORING ALGORITHMS: EXAMPLE

- Performance monitoring using Torque vs Speed characteristics of a 3-phase squirrel cage motor

Ideal curves reconstructed from data



Online monitoring using pattern recognition



Recommendations provided by the Application

Table 1: Summary of the fault conditions and actionable suggestions

Type of faults	Reason	Conditions it could represent	Actionable suggestions
Positive bias	The pump is producing more and/or against a higher head at the given speed	High torque/load, thrust failure	Increase the pump speed. This does not affect production
Negative bias	The pump is producing less and/or against a lesser head at the given speed	Low torque/load, thrust failure gas lock, pump off	Decrease the pump speed. This also does not affect production as the pump is already running in a low inventory state
High variance	Producing more gas	High gas production	Decrease pump speed if desirable. This can affect production

- Detect and track time spent on abnormal operating conditions and alert operations

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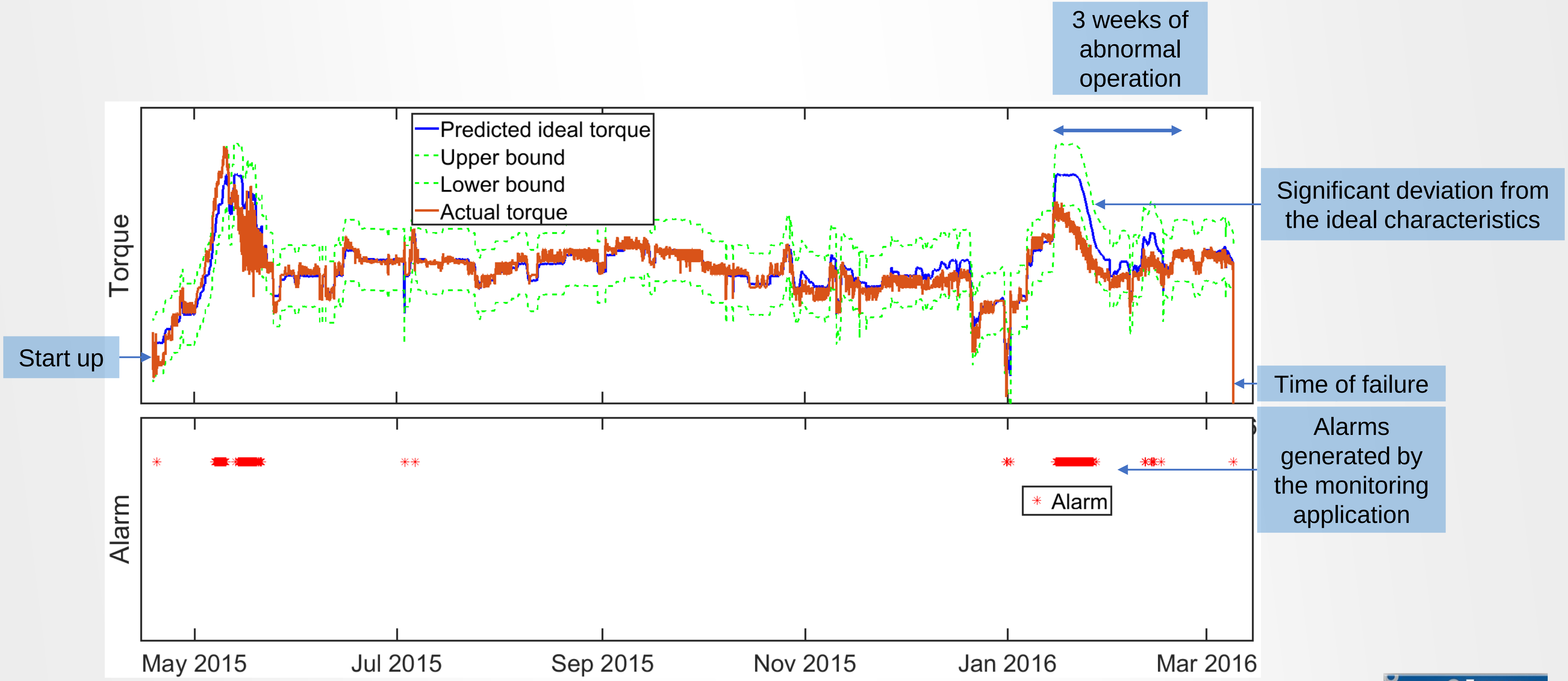
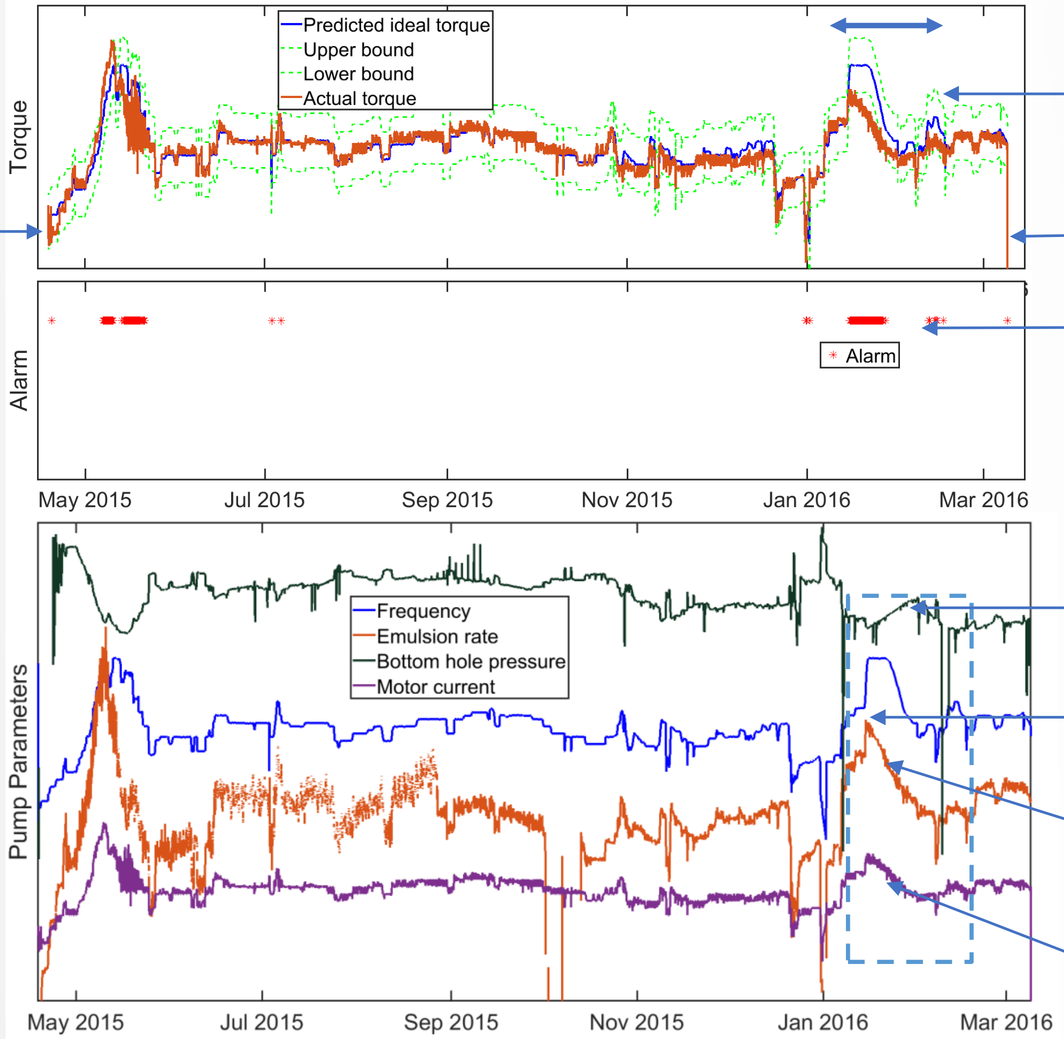
CASE STUDY



3 weeks of abnormal operation
Predicted ideal torque
Upper bound
Lower bound
Actual torque
Torque
Significant deviation from the ideal characteristics
Start up
Time of failure
Alarms generated by the monitoring application
Alarm
Alarm
May 2015
Jul 2015
Sep 2015
Nov 2015
Jan 2016
Mar 2016

CASE STUDY - ROOT CAUSE ANALYSIS

Start up



Significant deviation from the ideal characteristics, Indicating low load torque and pump-off conditions

Time of failure

Alarms generated by the monitoring application

BHP decreases initially and then starts to increase

Frequency is ramped up to a new state

Production rate is not sustained in the new state

Effect of decrease in head and decrease in flow can be seen in motor current

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PERFORMANCE MONITORING OF MULTIPLE ASSETS

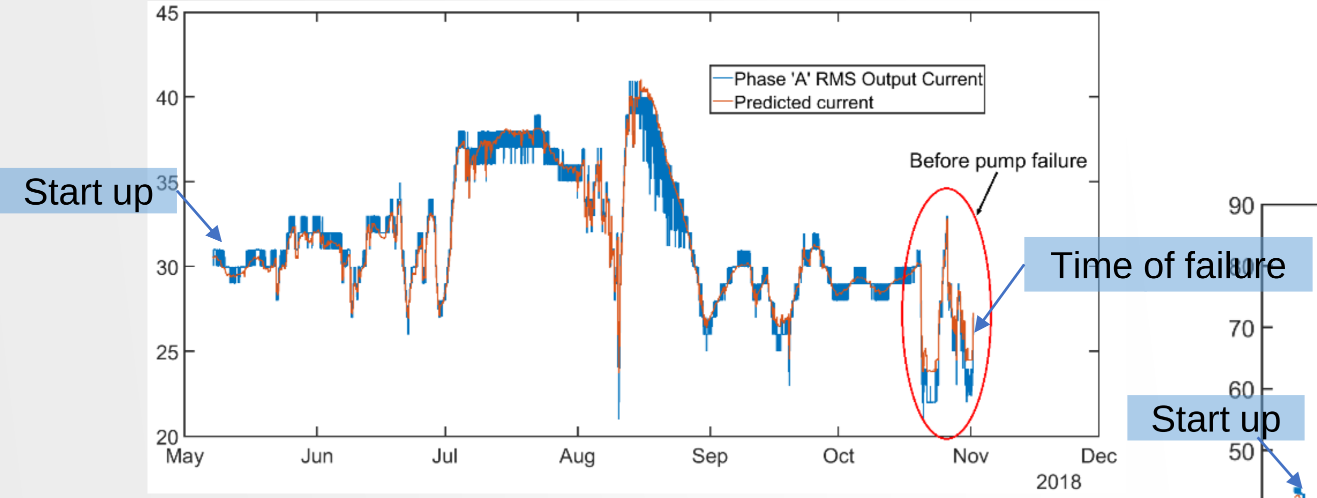
- R. I: Reliability index – Calculated based on the time spent on an abnormal operating condition
- 1 – Least amount of time spent on an abnormal operating condition, 0 – Most amount of time spent on an abnormal operating condition

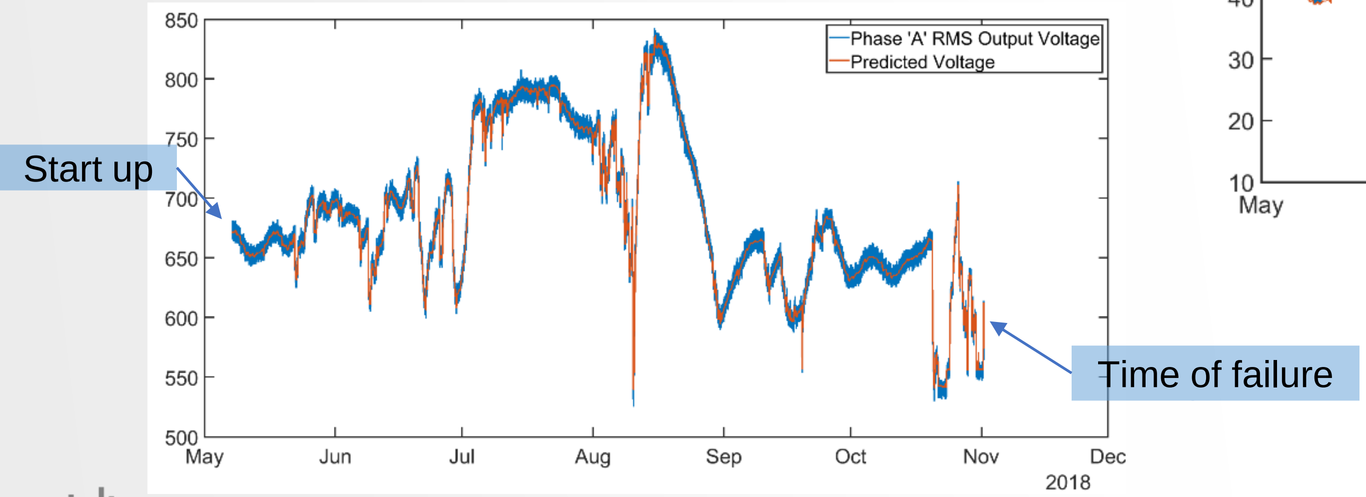
Asset#		R.I 1	R.I 2	R.I 3	Status	Runlife (days)
Asset 1		1	1	0.94	Running	710
Asset 2		1	0.961	1	Running	274
Asset 3		1	0.999	0.892	Running	477
Asset 4		0.94	0	0	About to fail	1142
Asset 5		0.927	0.977	0.923	Running	137
Asset 6		1	0.945	0.703	Running	363
Asset 7		1	0	0	About to fail	454
Asset 8		1	0.994	0.964	Running	1068
Asset 9		1	1	0.988	Running	195
Asset 10		1	0.861	0.846	Running	154
Asset 11		1	0.09	0.958	Failed	335
Asset 12		0	0	0	Failed	698
Asset 13		0	0	0.912	Failed	297
Asset 14		0.18	0.999	0.977	Failed	211
Asset 15		1	1	0.868	Failed	411

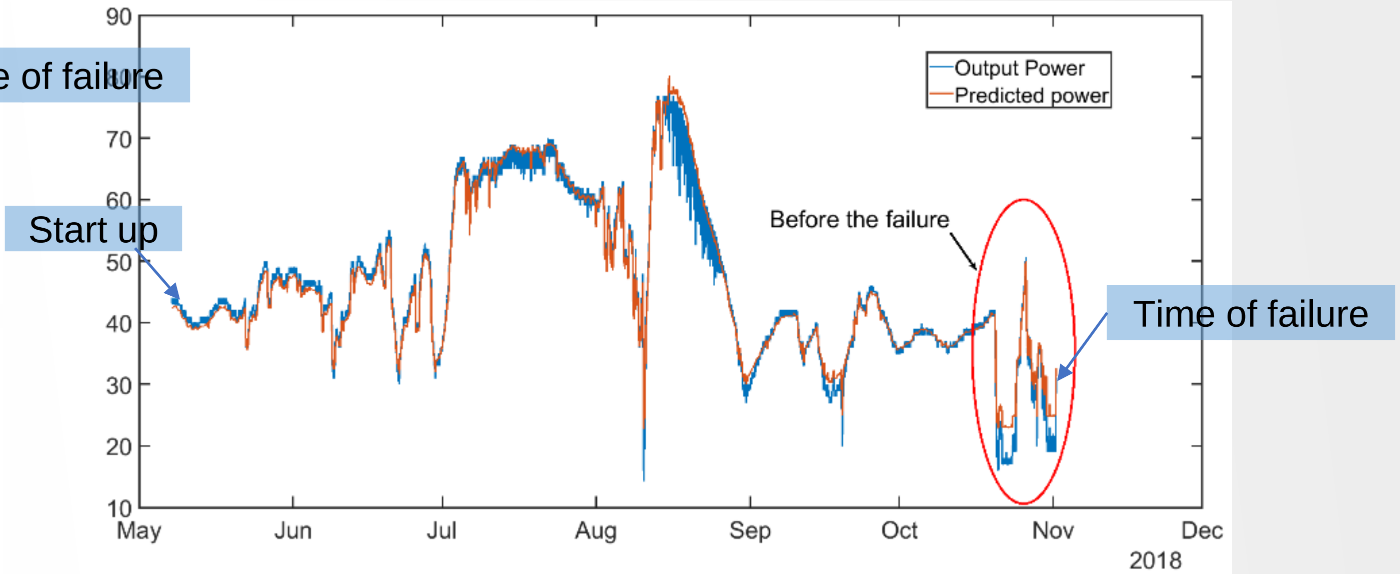
Asset#		R.I 1	R.I 2	R.I 3	Status	Runlife (days)
Asset 16		0	0.679	0.882	Failed	608
Asset 17		0.867	1	0.951	Failed	449
Asset 18		0	0	0.851	Failed	858
Asset 19		1	1	0.952	Failed	711
Asset 20		0.314	0	0.976	Failed	160
Asset 21		0.812	1	0.96	Running	762
Asset 22		1	0.999	0.963	Running	868
Asset 23		1	0	0.976	About to fail	744
Asset 24		0.873	0.695	0.893	Running	772
Asset 25		1	0.995	0.964	Running	936
Asset 26		1	0	0.934	About to fail	1061
Asset 27		1	0	0.976	Failed	443
Asset 28		1	0.736	0.892	Failed	277
Asset 29		1	0.312	0	Failed	991
Asset 30		0	0.999	0.976	Failed	734

MONITORING ALGORITHMS BASED ON VFD DATA: CASE STUDIES

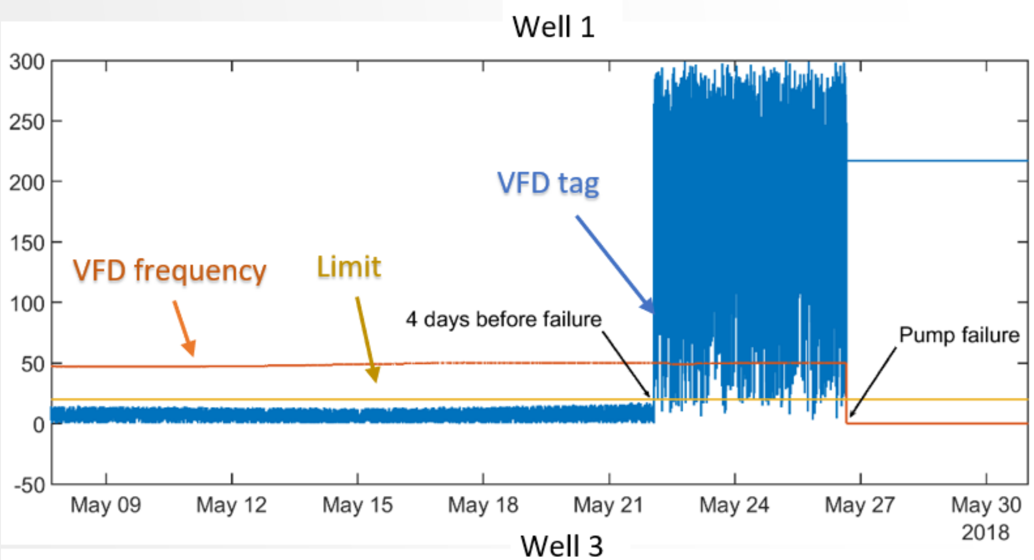
CASE STUDY 1: PHASE CURRENTS, VOLTAGES AND POWER

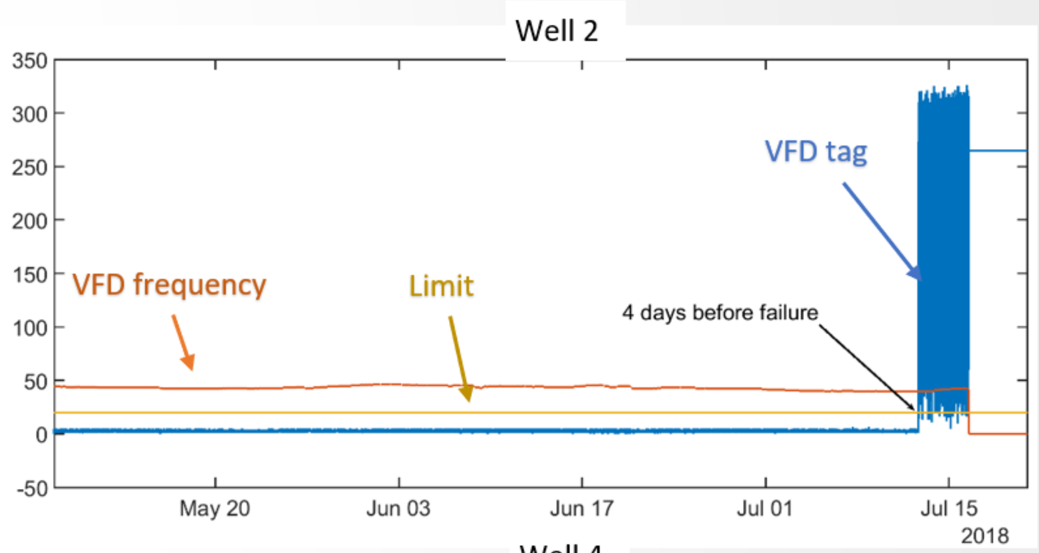


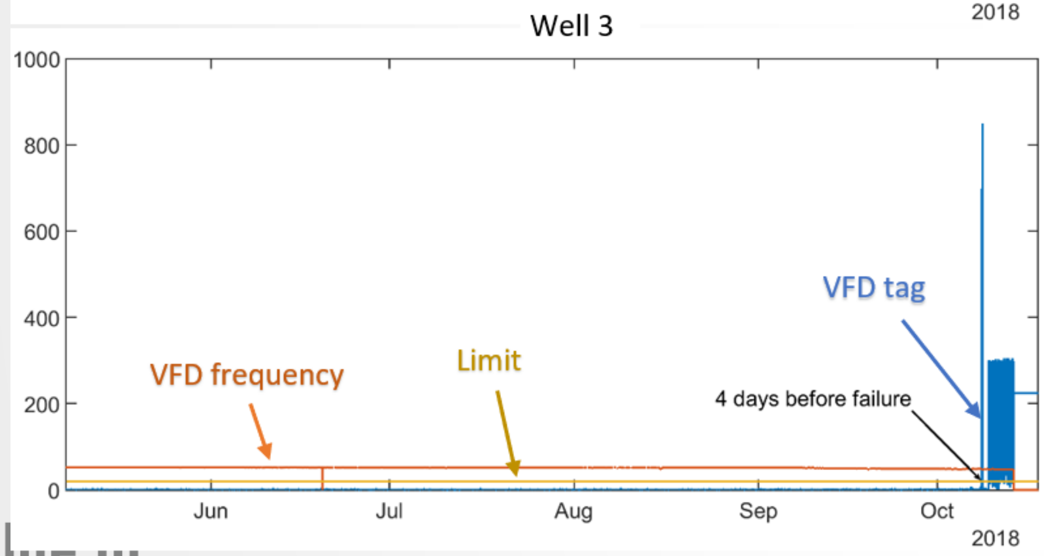


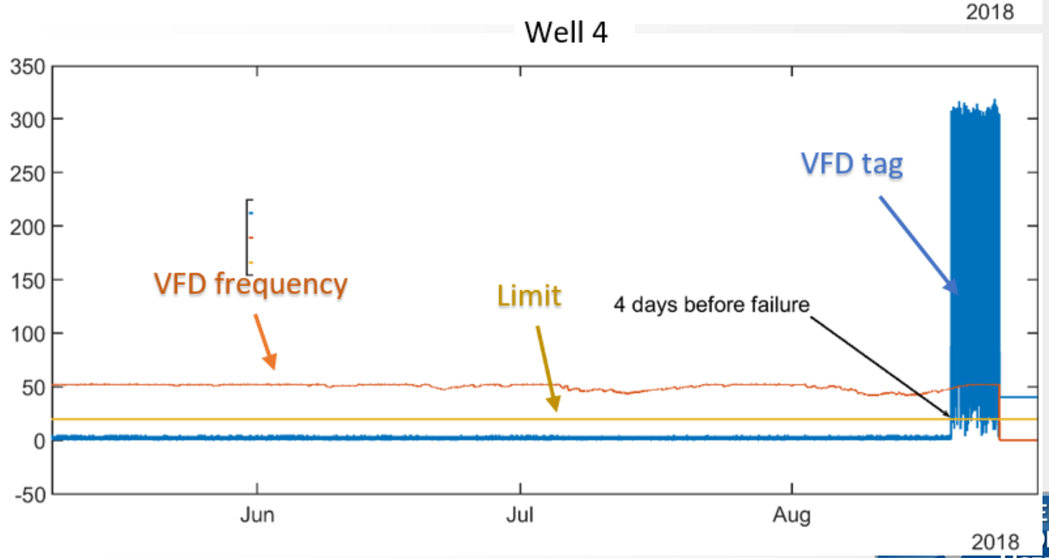


CASE STUDY2: SPECIFIC VFD TAGS FOR FAILURE PREDICTION

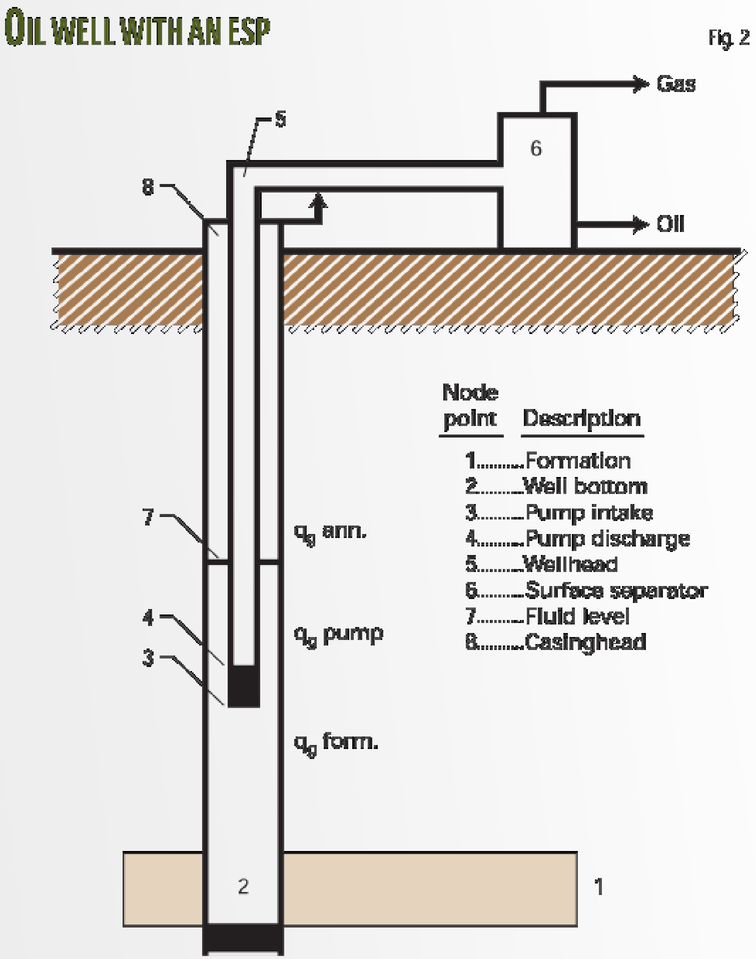


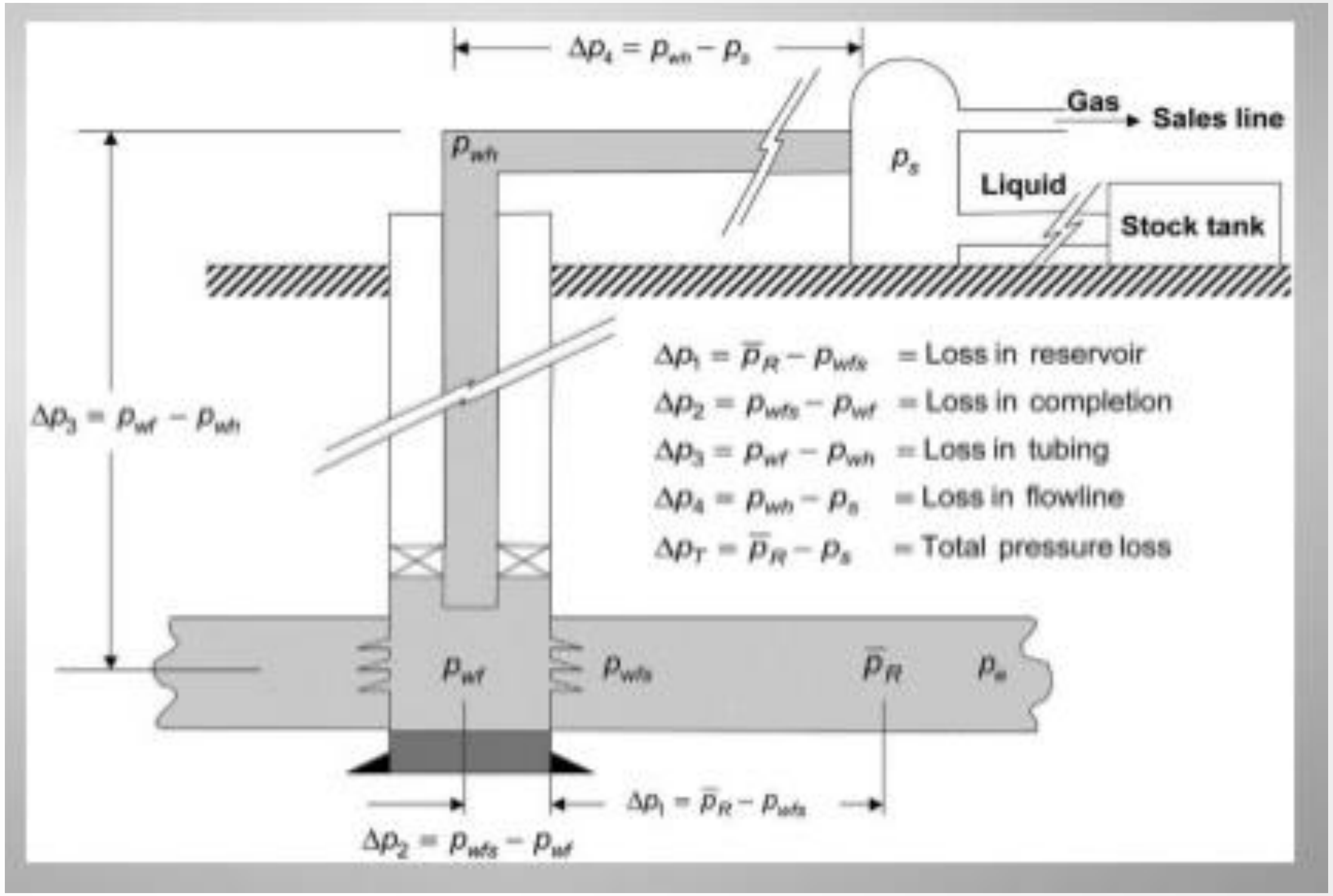




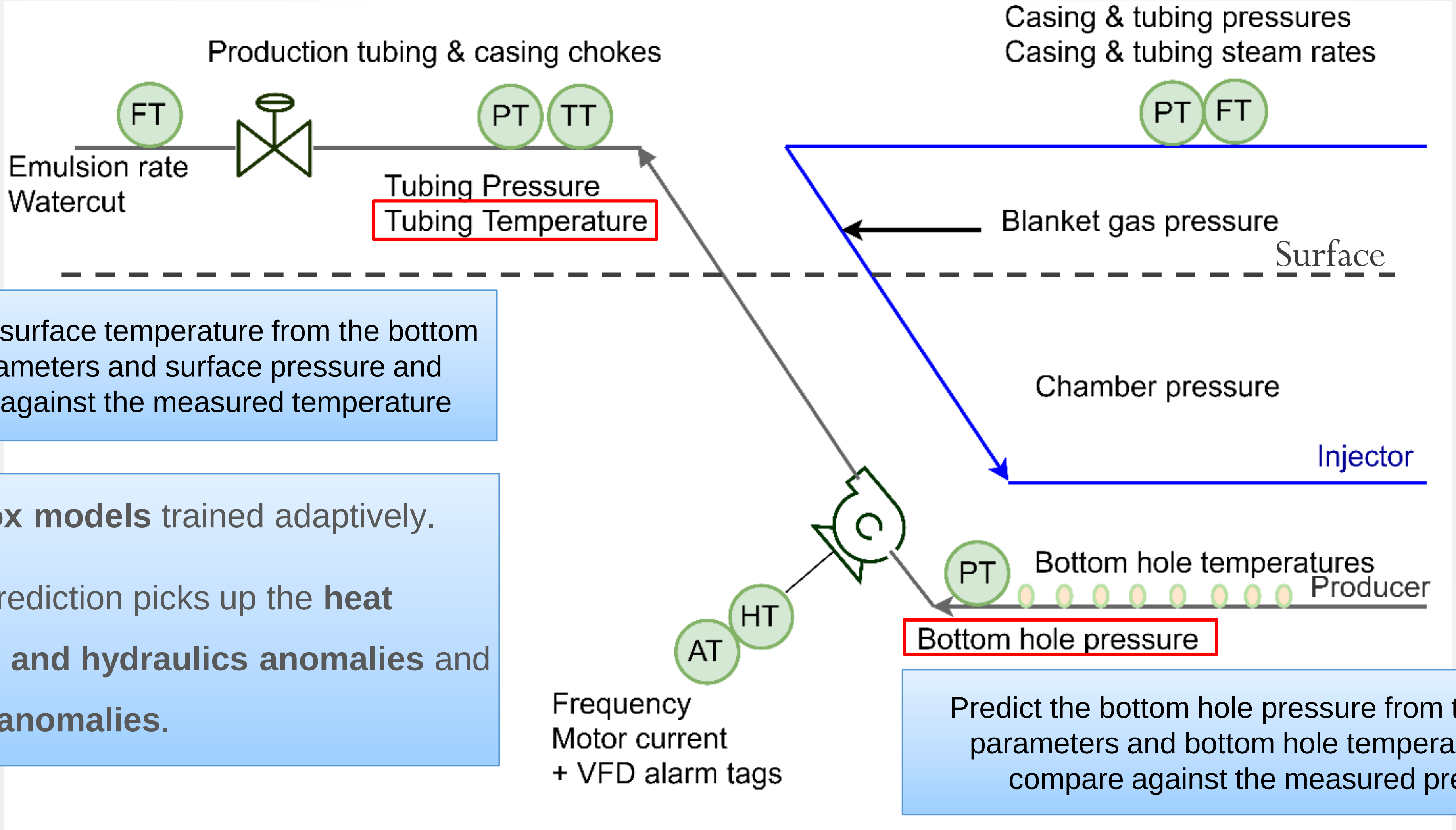


NODAL ANALYSIS APPROACH





MONITORING BASED ON DATA-DRIVEN NODAL ANALYSIS



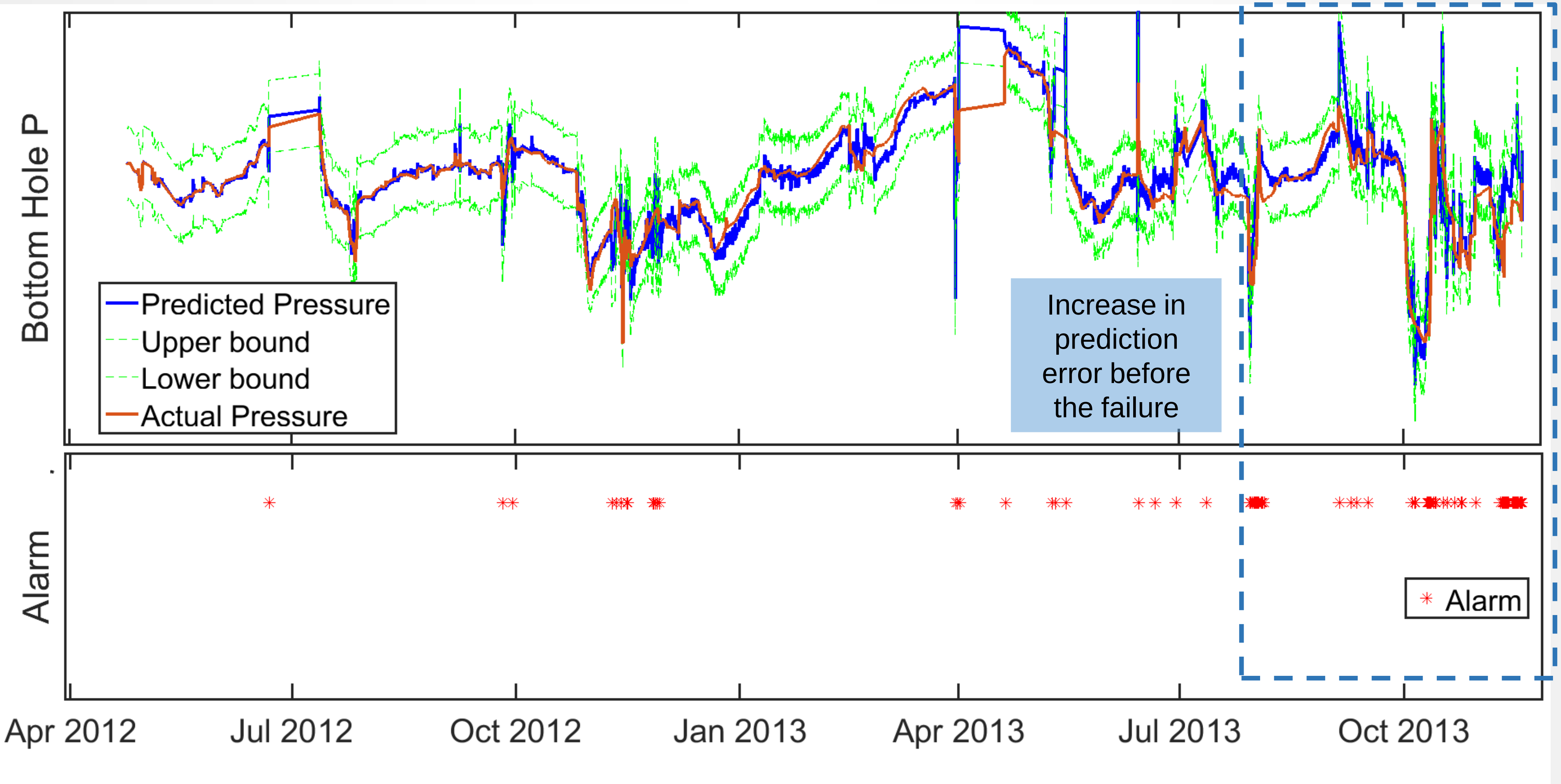
Predict the surface temperature from the bottom hole parameters and surface pressure and compare against the measured temperature

- **Grey-box models** trained adaptively.
- Model prediction picks up the **heat transfer and hydraulics anomalies** and **sensor anomalies**.

Predict the bottom hole pressure from the surface parameters and bottom hole temperatures and compare against the measured pressure

CASE STUDY: DATA-DRIVEN NODAL ANALYSIS

Start up

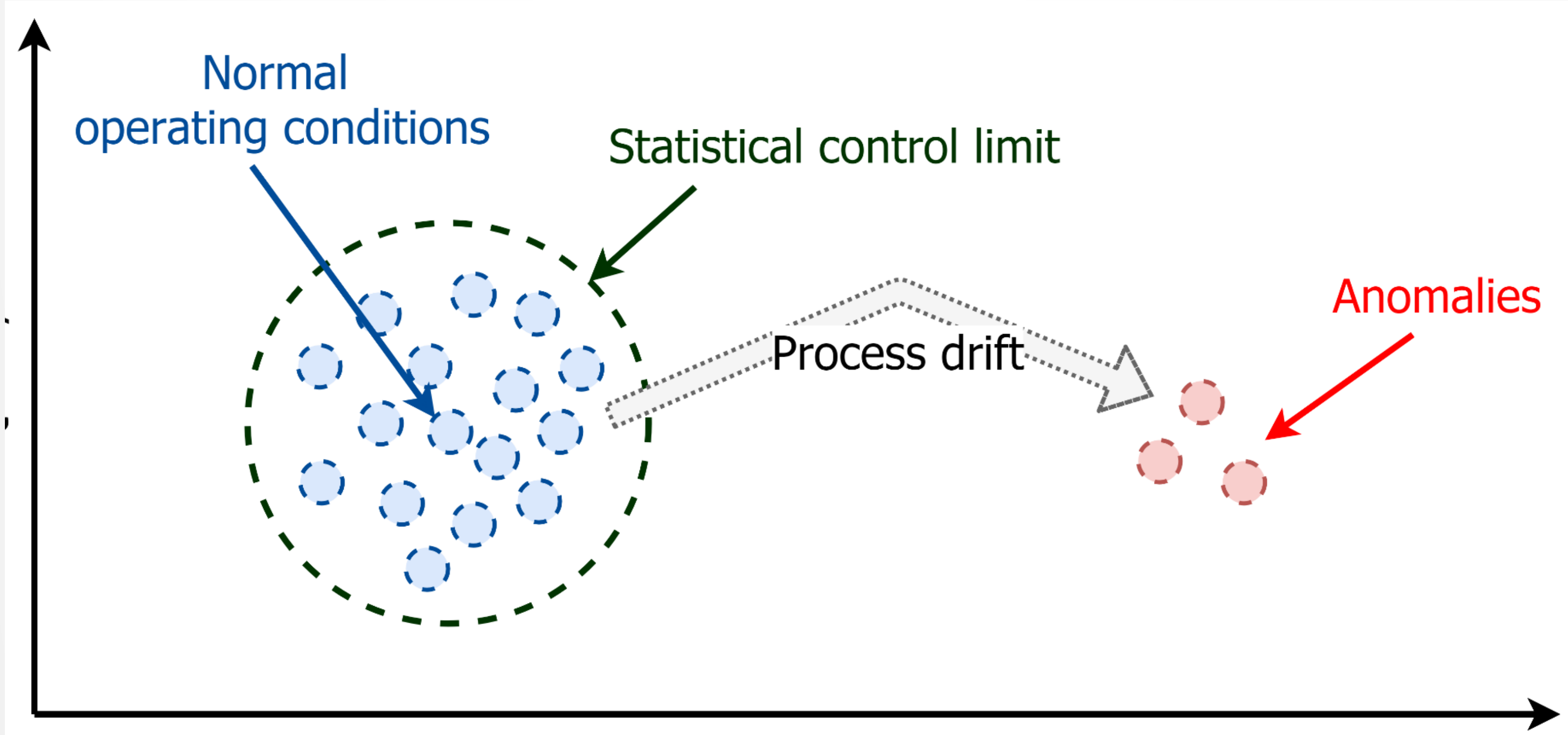


Time of failure

Alarms issued by the monitoring application

MACHINE LEARNING APPROACH

- Create a data-driven model that reduces high-dimension data to one or two process health indicators using data from normal operating conditions
- Determine statistical control limits from the data-driven model
- Detect process drifts online by monitoring the health indicators extracted from data



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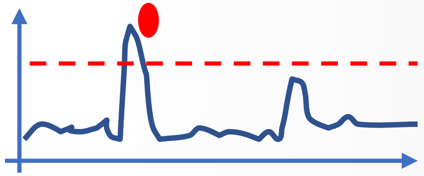
MACHINE LEARNING APPROACH

Composite detection metric



Higher level feature extraction

Group 1	Group 2	Group N
Detection metric	Detection metric	Detection metric
Feature extraction	Feature extraction	Feature extraction
Group 1 PVs	Group 2 PVs	Group N PVs

Available process data

Detect

Diagnose

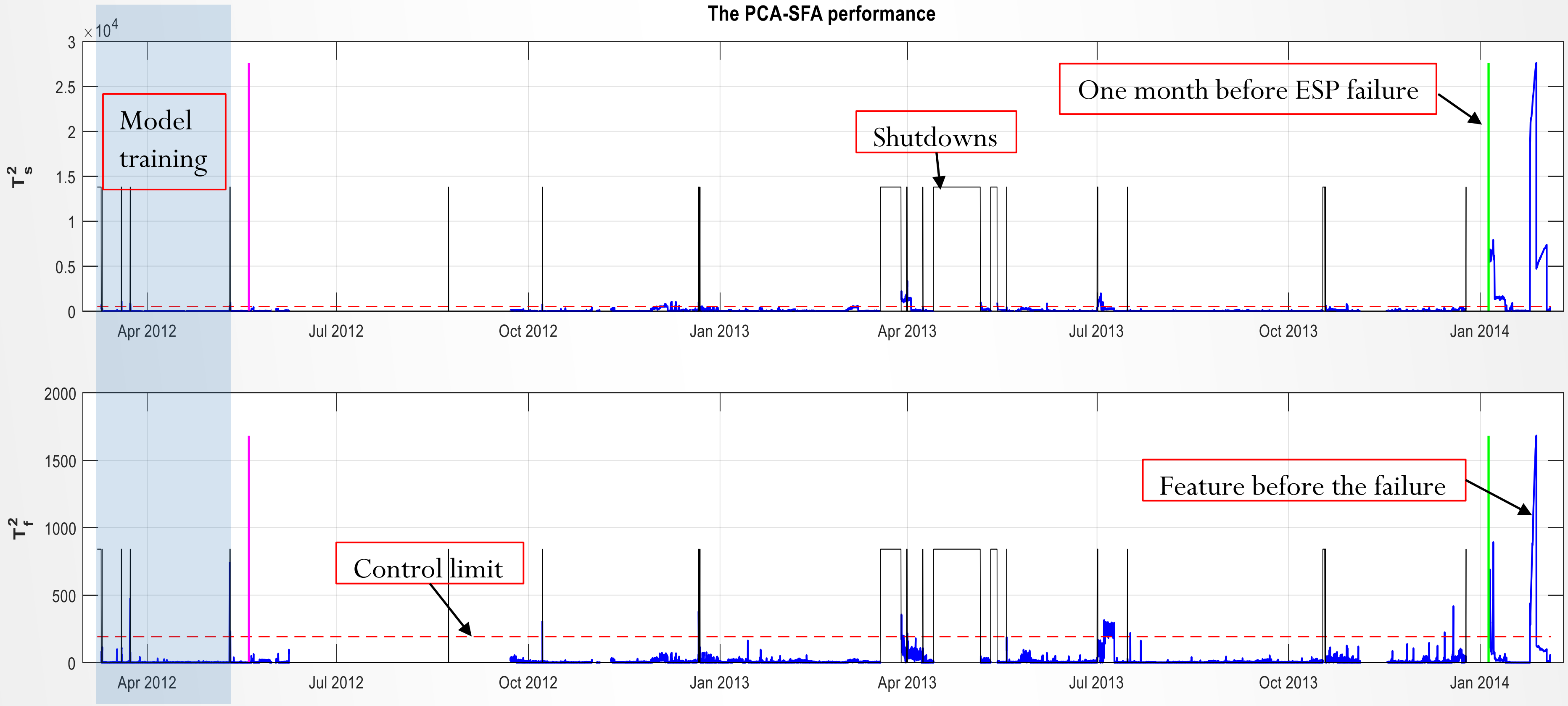
Monitor the process and equipment based on one or two indicators

Fuse features from different groups and perform dimension reduction

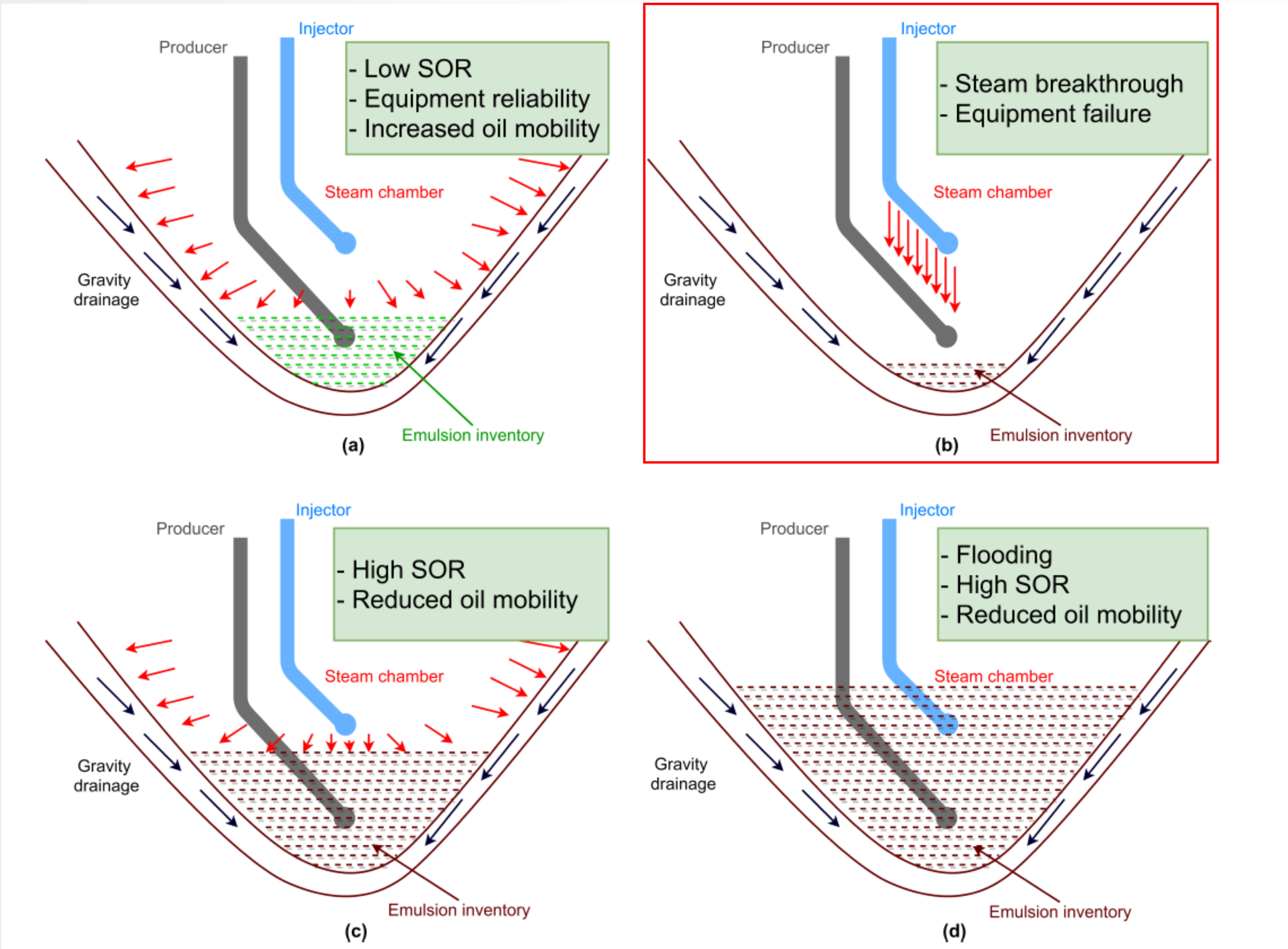
Perform dimension reduction and capture features that explain the variability in the data

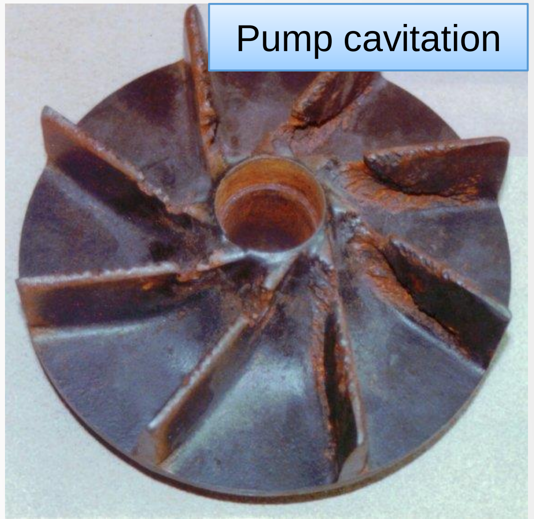
Combine process knowledge and high-dimension data to group process variables

MACHINE LEARNING APPROACH: CASE STUDY

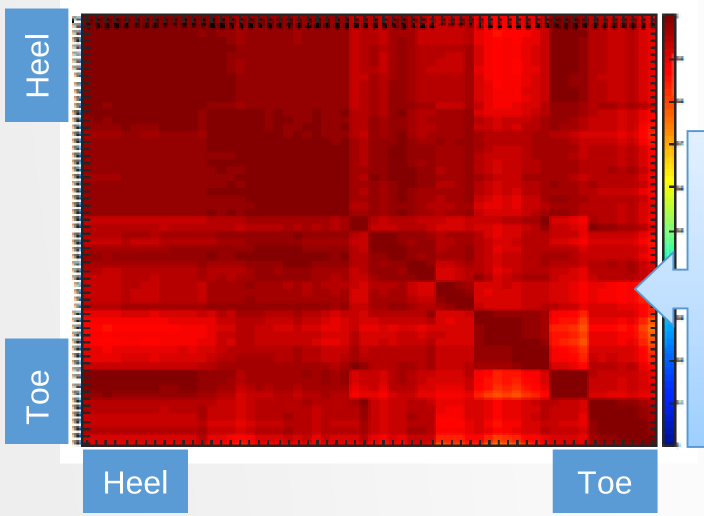


MONITORING ABNORMAL OPERATING CONDITIONS

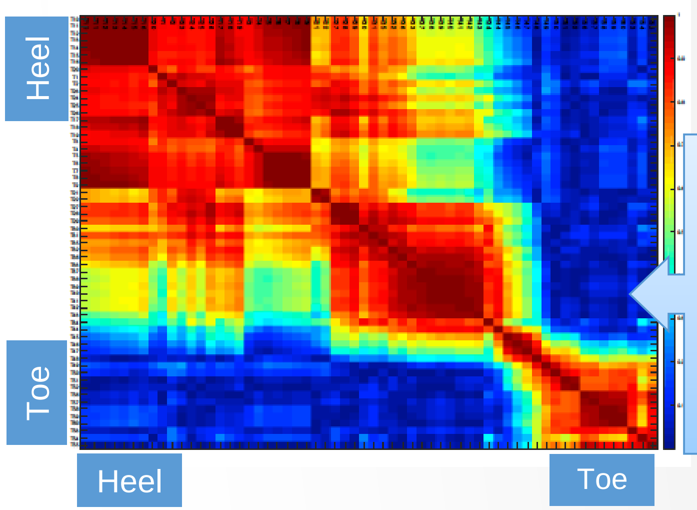




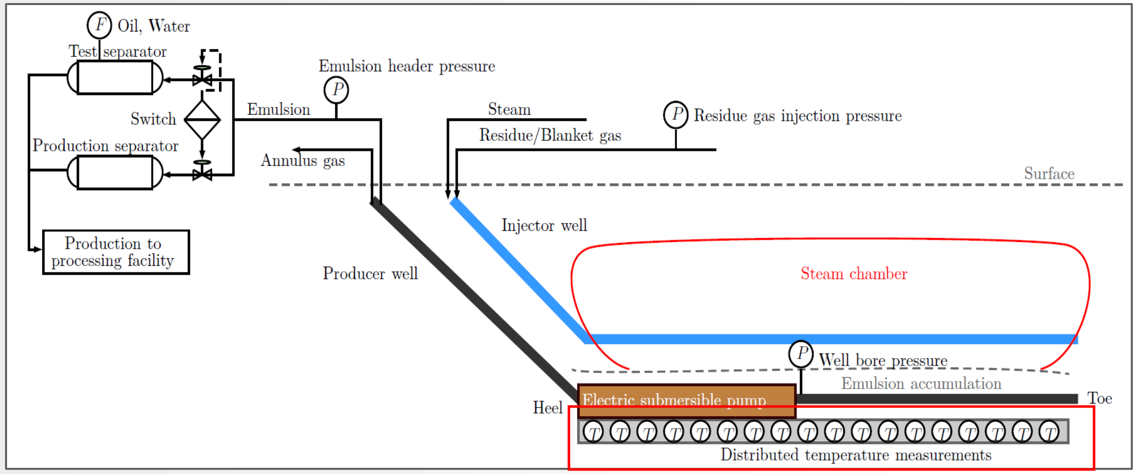
MACHINE LEARNING TO PREDICT STEAM BREAKTHROUGH



Correlation matrix of the temperatures measured along the wellbore **during normal operation**

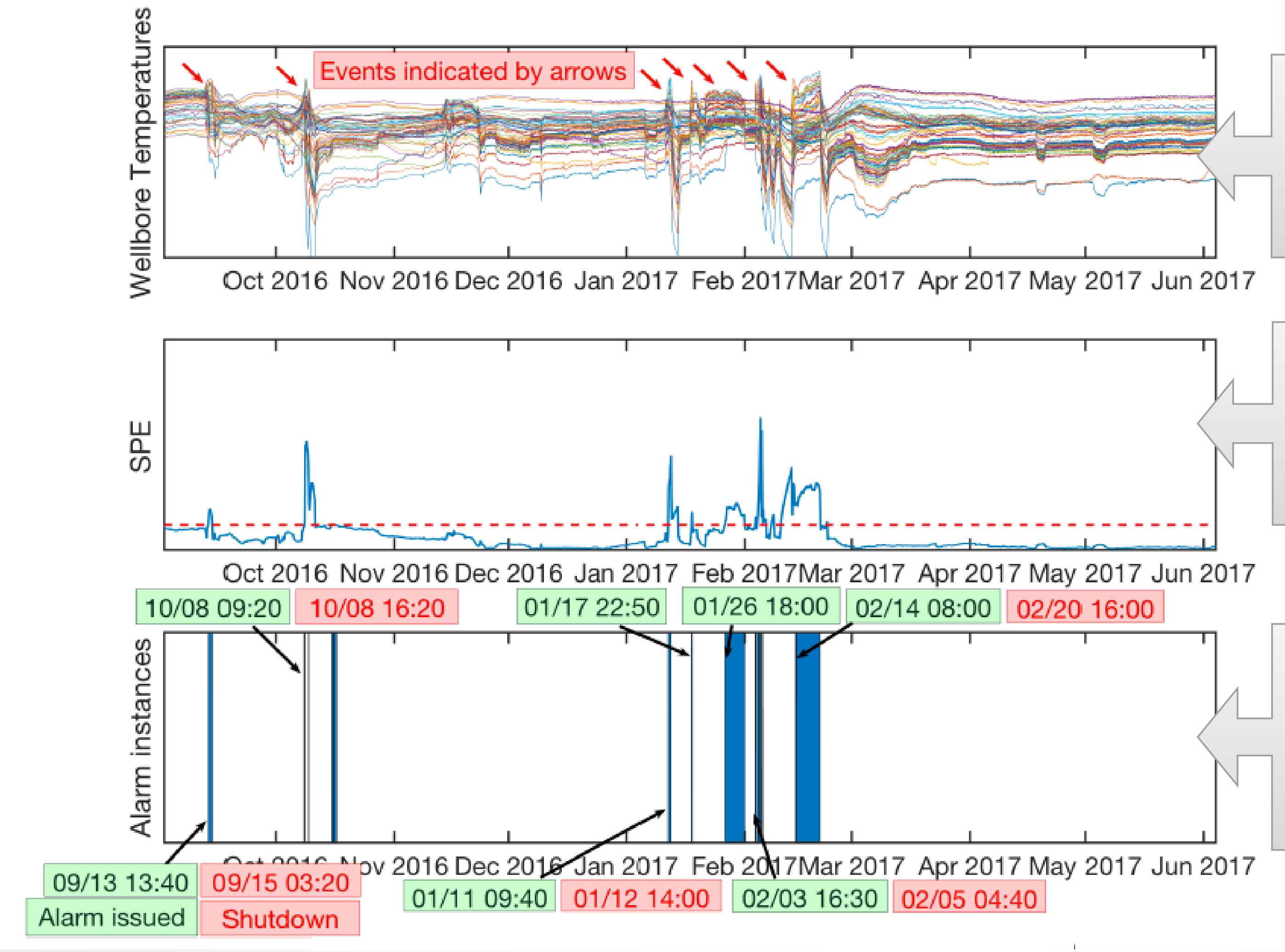


Correlation matrix of the temperatures measured along the wellbore **just before the incidents**



- Patterns in temperature measurements along the wellbore used to predict some of the abnormal incidents
- When steam breaks through some parts of the well, measured temperatures in those parts tend to have distinct trends compared to the rest of the well

STEAM BREAKTHROUGH PREDICTION RESULTS



Trends of temperatures measured along the well bore

Temperature measurements reduced to a single monitoring statistic

Alarms issued by the monitoring tool

EMERSON'S DATA ANALYTICS PLATFORM

- Platform developed by Integration Objects, Tunisia-based company
- Acquired by Emerson in April, 2019
- To be integrated with Emerson's Plantweb digital ecosystem

KnowledgeNet

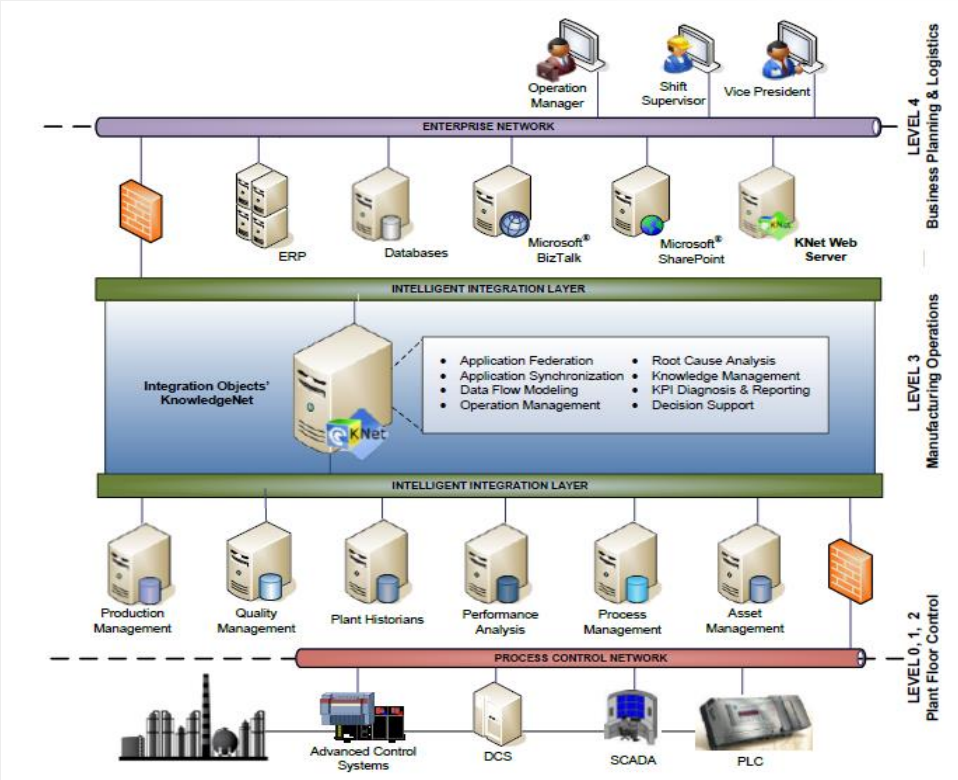
A Unique Platform for Your Digital Transformation

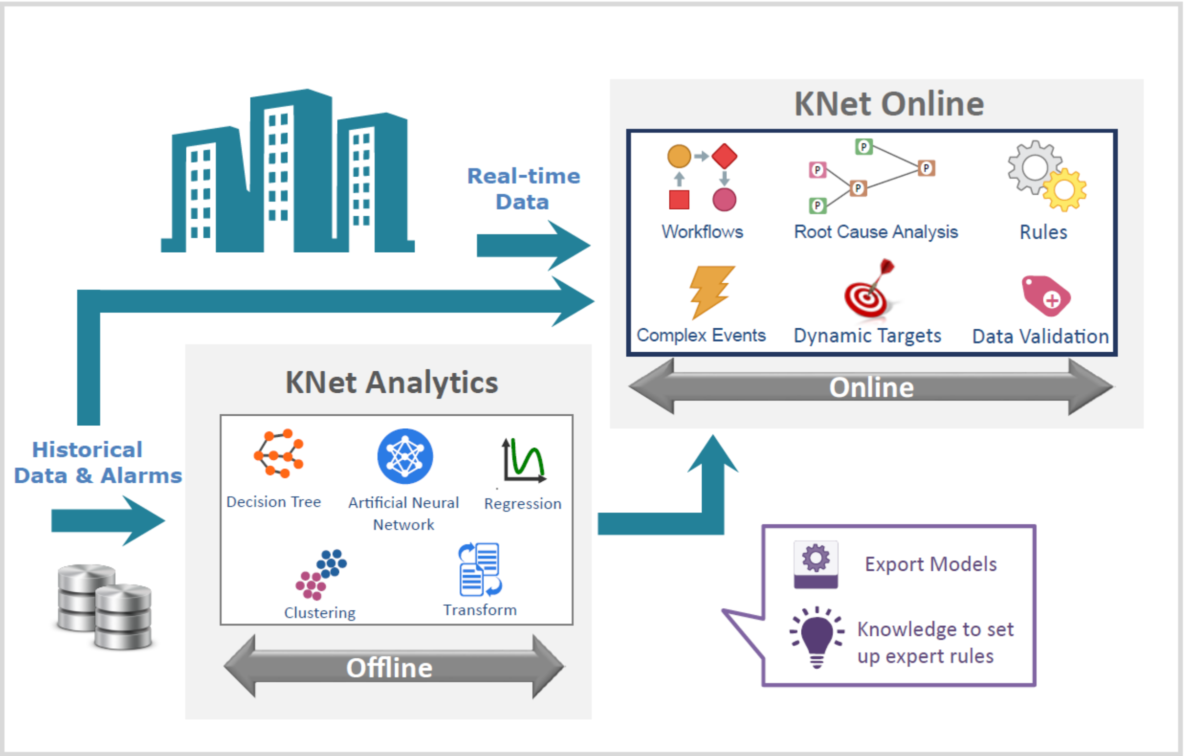
KnowledgeNet (KNet) platform is primarily used to empower operations in the chemical, oil and gas, power, and utilities industries in making timely business decisions to increase production uptime, profitability, and safety. KNet supports cloud platforms and offers to end users a cutting edge technology to migrate to Industry 4.0. Users may include operators, shift supervisors, engineers, and plant managers.

KnowledgeNet helps you digitize your plant to future proof your operations and improve your assets performance and reliability.

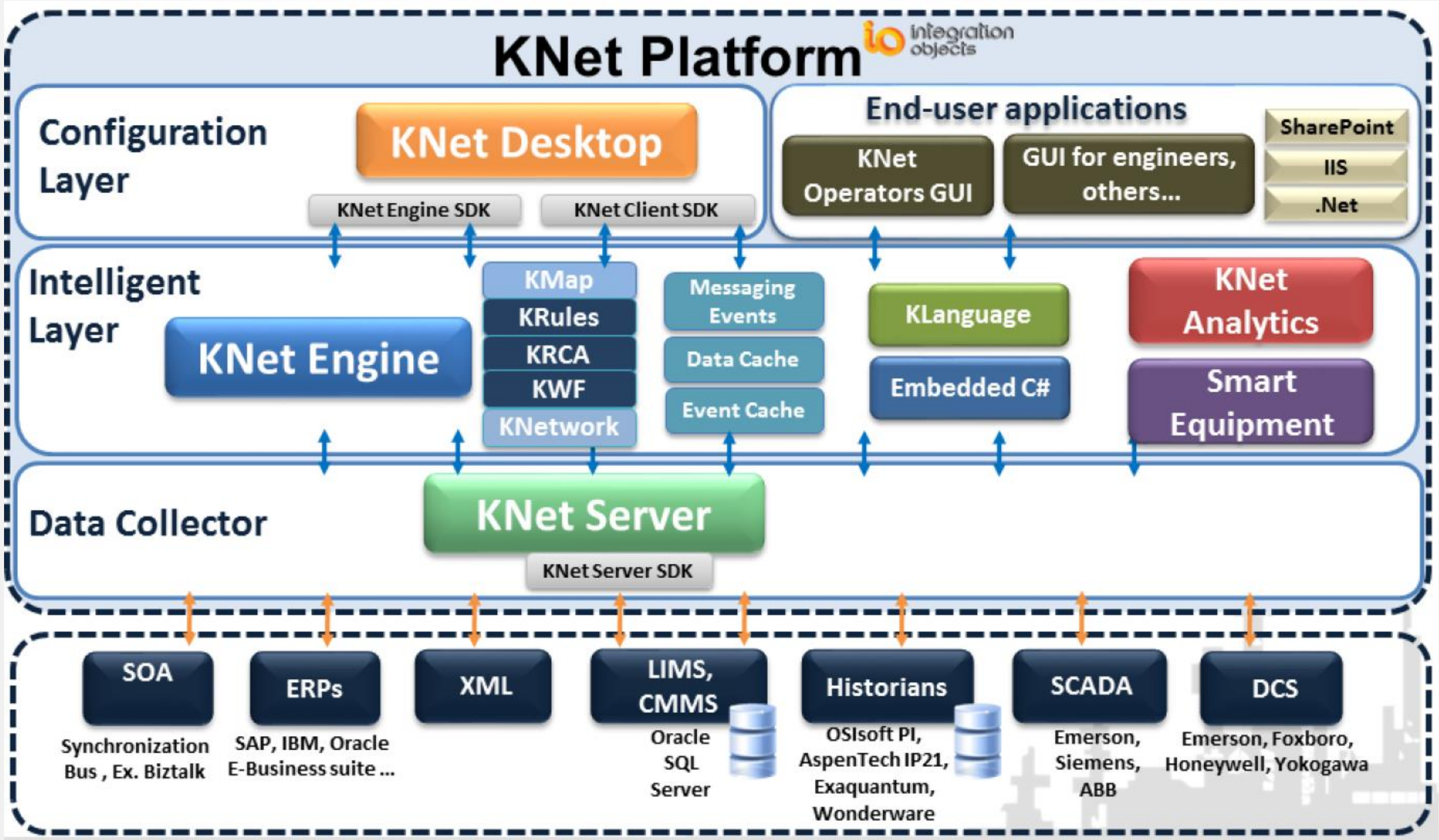
KNET SOFTWARE FEATURES

- Includes a number of in-built tools for data connectivity, preprocessing and data analytics, automated root cause analysis, alarm analytics, etc.
- Easy to compile and drop custom-built algorithms for monitoring and prediction applications



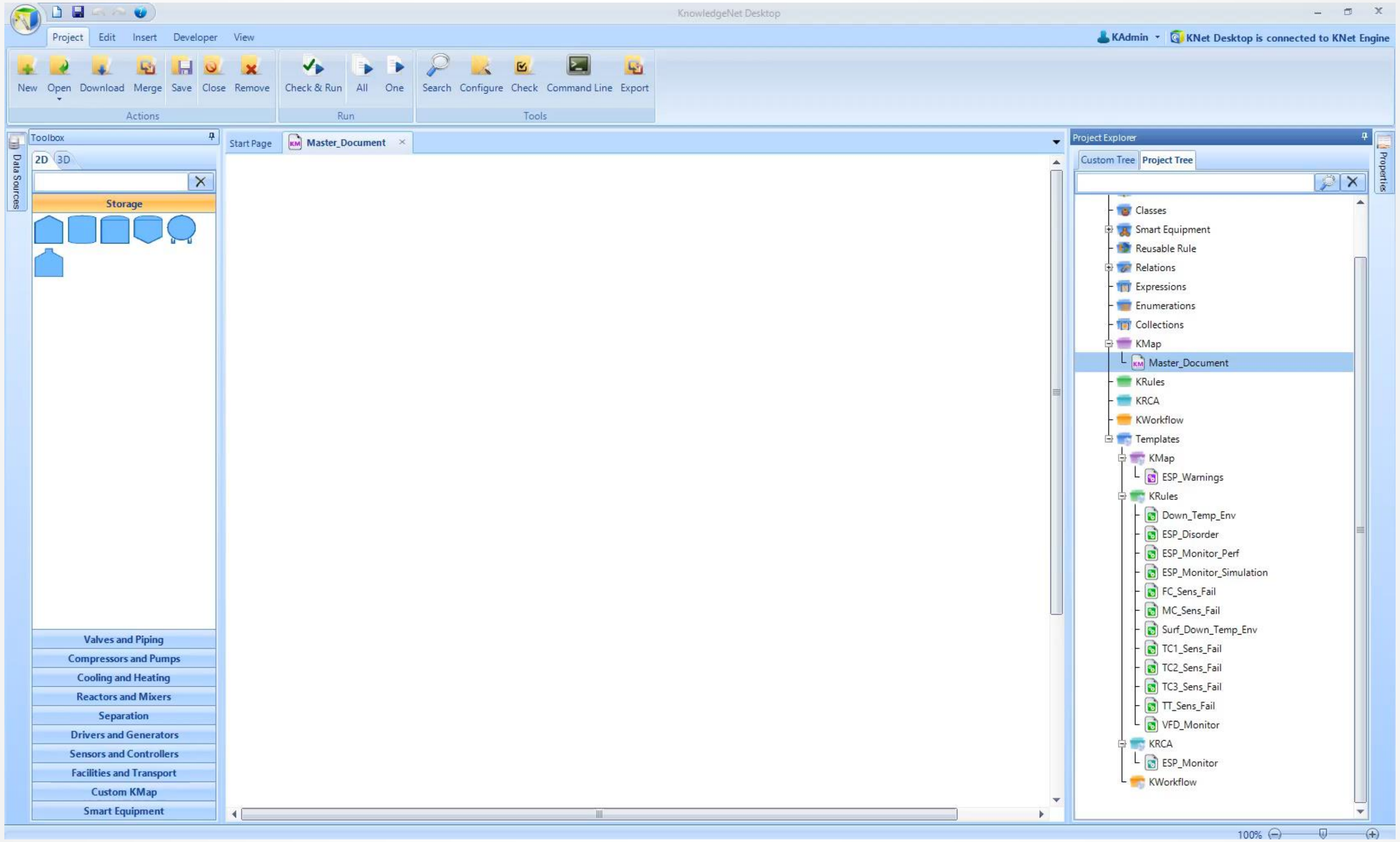


KNET: MAIN COMPONENTS AND DETAILED ARCHITECTURE



ESP MONITORING IN EMERSON'S ANALYTICS PLATFORM

- All our algorithms are built, deployed and tested in KNET online
- Research to deployment – A fast route



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BUSINESS RESULTS ACHIEVED

- Field Trial:
  - The performance monitoring application is currently being field tested with one of the producers in the province to assess the financial benefits.
- Joint Industrial Project:
  - A JIP to study data from multiple ESP installs at multiple producer sites has been initiated in collaboration with Canadian Oil Sands Innovation Alliance (COSIA)
- Potential benefits:
  - There are about 1100 thermal oil wells equipped with ESPs in Alberta
  - One less rig over per well on an average can provide over 300 million dollars savings to the industry

SUMMARY

- Electric submersible pumps (ESPs) are widely preferred artificial lift systems in upstream oil production
- Keeping the ESPs operational is one of the important challenges faced by the operators
- Under the Industrial Research Chair, we have been investigating a number of different data-driven algorithms for fault detection, diagnosis and failure prediction of ESPs
- Emerson’s analytics platform with its data connectivity and analytics capability allows taking the research results to the field in a quick and easy manner
- Field tests are being conducted to properly assess the financial benefits

WHERE TO GET MORE INFORMATION

- Industrial research chair program:
  - https://www.ualberta.ca/engineering/research/groups/oil-sands-process-control
- Spartan Controls
  - https://www.spartancontrols.com/
- ESP Resources:
  - https://www.elsevier.com/books/electrical-submersible-pumps-manual/takacs/978-1-85617-557-9
  - http://jip.esprifts.com/
  - https://www.onepetro.org/conference-paper/SPE-56663-MS
  - https://www.onepetro.org/conference-paper/IPTC-17413-MS
- Analytics platform
  - https://www.emerson.com/en-ca/news/corporate/emerson-acquires-knet-software
  - https://integrationobjects.com/digital-transformation/products/knowledgenet/

WHEN PRESENTATIONS WILL BE AVAILABLE

- Presentations will be made available to registered attendees a few weeks after the conference.
- They will be available in emersonexchange365.com. You must be a member of EE365 to access them. Join the community now!
- Attendees will receive an email from the conference organizers when presentations are ready to be downloaded.

THANK YOU FOR ATTENDING!

Remember to rate this session in the mobile app, and enjoy the rest of the conference!

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