10th Chemical Process Safety Sharing (CPSS)

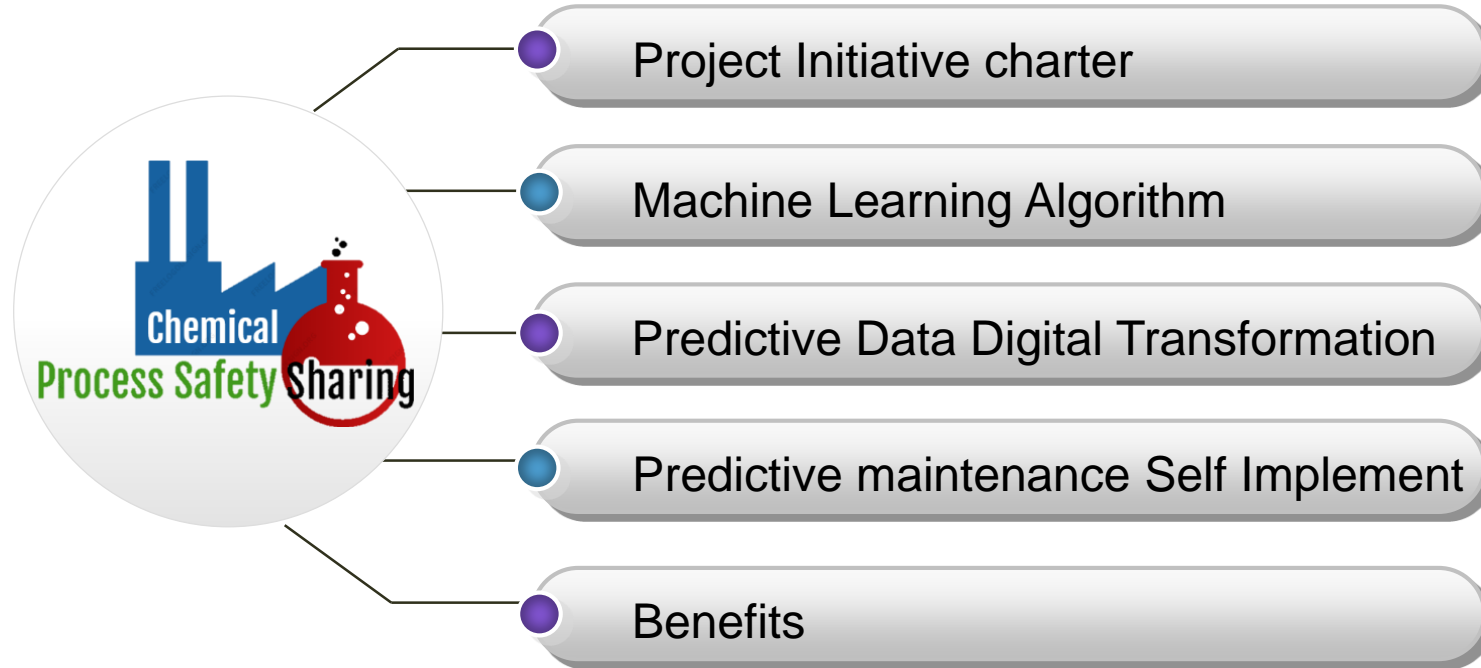## Topic: Predictive Rotating Digital Transformation

Presenter : K. Theerayut Phonrut
E-mail: theerayut.p@irpc.co.th
Company : IRPC

SCGC   GC   IRPC   Thaioil   TIChE

Contents

- Project Initiative charter
- Machine Learning Algorithm
- Predictive Data Digital Transformation
- Predictive maintenance Self Implement
- Benefits

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Predictive Rotating : Project Initiative charter

Objectives

Margin
- Avoid margin lost linked to unit unplanned failure

Cost
- Limited maintenance OpEx and CapEx thanks to failure prediction and consequent minor intervention required

Business problem/ pain points
- Reliability of monomer recovery compressor
- Vibration analysis on critical rotating machine without advanced predictive algorithm
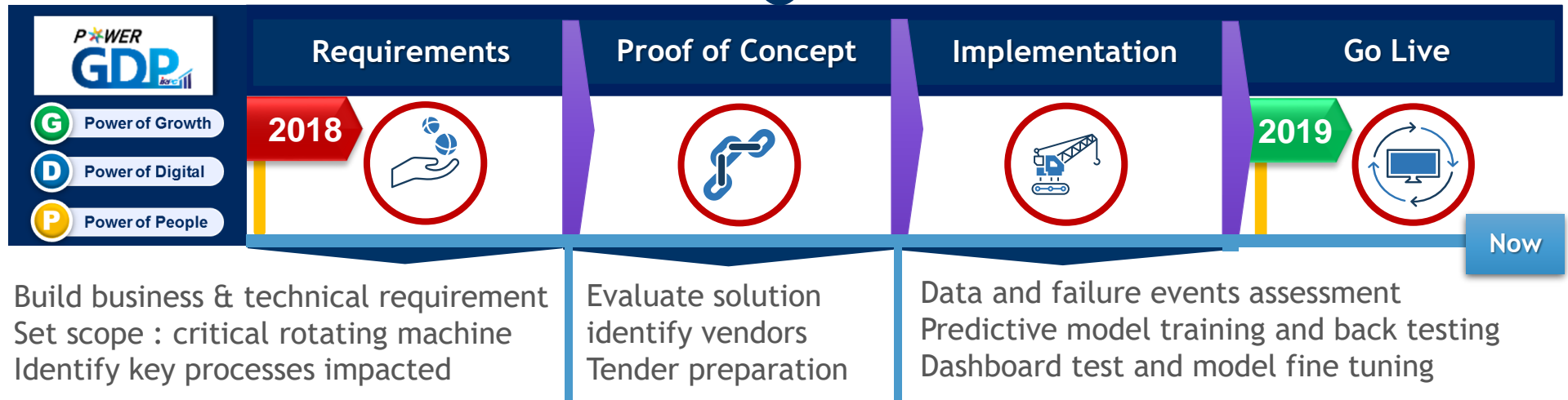
Equip with new advanced digital tool

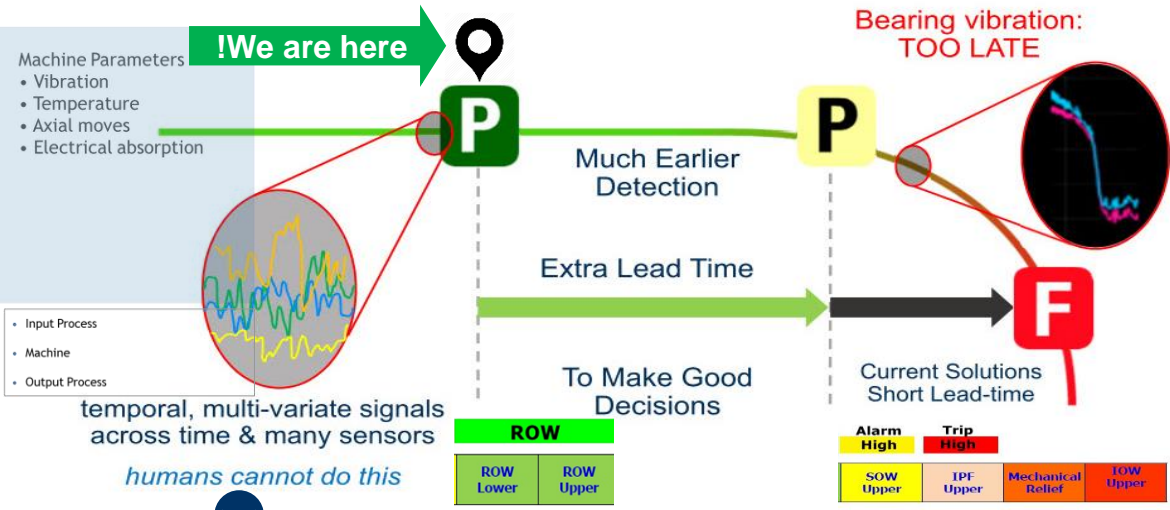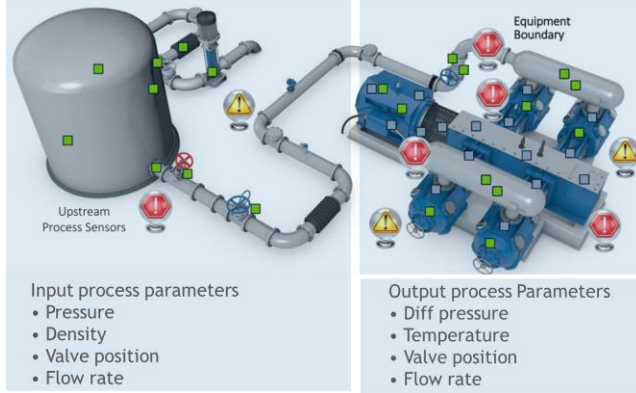data driven for better decision making

Less time spent on manual work

Keeping us connected

POWER GDP
- **G** Power of Growth
- **D** Power of Digital
- **P** Power of People

Requirements	Proof of Concept	Implementation	Go Live
2018			2019
Build business & technical requirement	Evaluate solution identify vendors	Data and failure events assessment	
Set scope : critical rotating machine	Tender preparation	Predictive model training and back testing	
Identify key processes impacted		Dashboard test and model fine tuning	

Now

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Predictive Rotating : Project Initiative charter

Sensors Groups On & Around Equipment

Machine Parameters
• Vibration
• Temperature
• Axial moves
• Electrical absorption

!We are here

Bearing vibration: TOO LATE

Much Earlier Detection

Extra Lead Time

To Make Good Decisions

Current Solutions Short Lead-time

Equipment Boundary

Upstream Process Sensors

Input process parameters
• Pressure
• Density
• Valve position
• Flow rate

Output process Parameters
• Diff pressure
• Temperature
• Valve position
• Flow rate

• Input Process
• Machine
• Output Process

temporal, multi-variate signals across time & many sensors

humans cannot do this

ROW

ROW Lower | ROW Upper

Alarm High | Trip High

SOW Upper | IPF Upper | Mechanical Relief | IOW Upper

C1- O4 Predictive rotating machines : Overview
Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL)

Artificial Intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans.

ARTIFICIAL INTELLIGENCE
Early artificial intelligence stirs excitement.

Machine Learning (ML) is the scientific study of algorithms and statistical models that computer systems use to progressively improve their performance on a specific task. Machine learning algorithms build a mathematical model of sample data, known as "training data"

MACHINE LEARNING
Machine learning begins to flourish.

Deep Learning (DL) is part of a broader family of machine learning methods based on learning data representations, as opposed to task-specific algorithms.

DEEP LEARNING
Deep learning breakthroughs drive AI boom.

1950's 1960's 1970's 1980's 1990's 2000's 2010's

connect   import   combine   analyze   present

Install Mtell & Connect to Data Sources

Import Data & Validate

Create, Tune & Deploy Live Agents

Monitor & Manage Asset Health Workflows

SAP

Honeywell

Import Equipment Work Order History

Import Historian Data

Hidden Failures

Failure Agent

Anomaly Agent

Email Alert

Work Order

Mtell View

Machine intelligent Prediction : Information Flow

Machine	DCS	PHD	Machine Learning Algorithm	Action

Failure Agent

Gearbox → Mechanical Wear → ⛔ → Gear

Bearing → Mechanical Wear → ⛔ → Bearing

Baseline   Anomaly   Failure

Anomaly Agent

Trip Level

Alarm Level   Anomaly   Process variable

Normal Operating Range   Predicted Value

Machine   Anomaly   Process

Temp
Pressure
Flow
Level
Vibration

Honeywell

SAP ERP

Anomaly Agent
Production lead discussion (if need)
IRI issue notification (if need)
IRI acknowledge and train agent
END

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Implementation Scope : Final 20 Equipment Roll Out 2019

	ID	Plant	Equipment N	FL	Description
T/A	1	DCC	31K002	DCC -31 -31K002 -K01	Wet Gas Compressor
T/A	2	DCC	33K001	DCC -33 -33K001 -K01	Light Ends Gas Compressor
	3	DCC	34K001	DCC -34 -34K001 -K01	C3 Refrigerant Compressor
	4	DCC	34K002	DCC -34 -34K002 -K01	Heat Pump Compressor
	5	ETP	C3101	HOT -31 -C3101	Cracked Gas Compressor
	6	ETP	C4401	CLD1-44 -C4401	Ethylene Compressor
	7	ETP	C4601	CLD1-46 -C4601	Propylene Compressor
T/A	8	RDCC	53K001	RDCC-53 -53K001	Air BlowerPackage(w/MTR)
T/A	9	RDCC	53K101	RDCC-53 -53K101	Wet GasCompressor(w/TBN)
T/A	10	RDCC	58K001	ERU -58 -58K001	Light EndGasCompressor(w/MTR)
T/A	11	RDCC	58K401	ERU -58 -58K401	C2 HeatPump/Refrig.Compressor(w/
T/A	12	RDCC	58K501	ERU -58 -58K501	C3RefrigerationCompressor(w/MTR)
	13	PRP	K7401	C42P-74 -K7401 -C01	Refrigerant Compressor
	14	EBSM	03K001	EBSM-03 -03K001 -C01	OFF GAS COMPRESSOR
	15	LTU	23K001	LTU -23 -23K001	LC PROPANE COMPRESSOR
T/A	16	NTU	12K001	NTU -12 -12K001	12K001 COMPRESSOR LOCAL CONTRO
	17	VGOH	30K001A	VGOH-30 -30K001A	Make up & Recycle Gas compressor
	18	VGOH	30K001B	VGOH-30 -30K001B	Make up & Recycle Gas compressor
	19	PP	40K010	PP -40 -40K010	LC TOP COMPRESSOR
	20	PP	90RN10	PP -90 -90RN10	Agitator

Machine Selection

DCC: 4, EBSM: 2, ETP: 5, LTU: 1, NTU: 1, PP: 5, PRP: 1, RDCC: 5, VGOH: 2
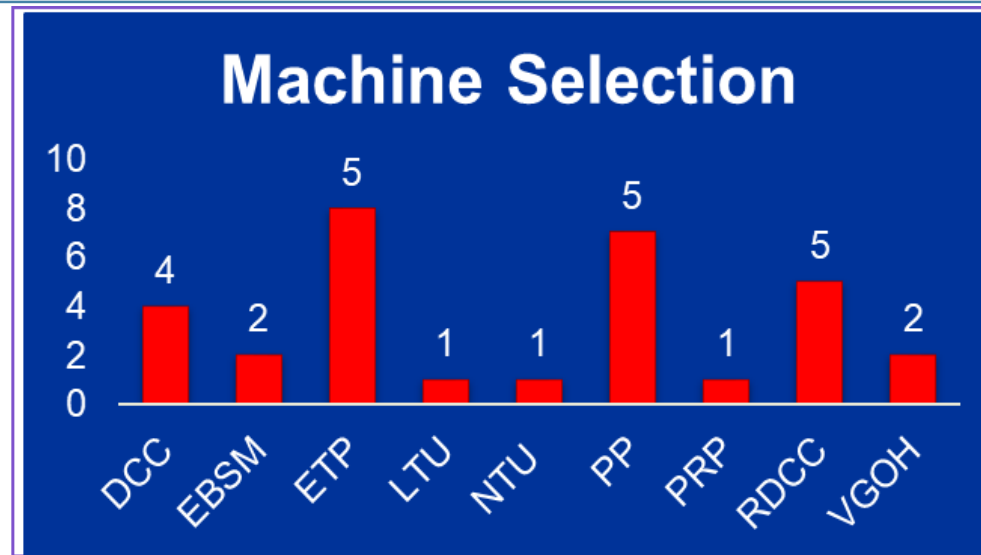
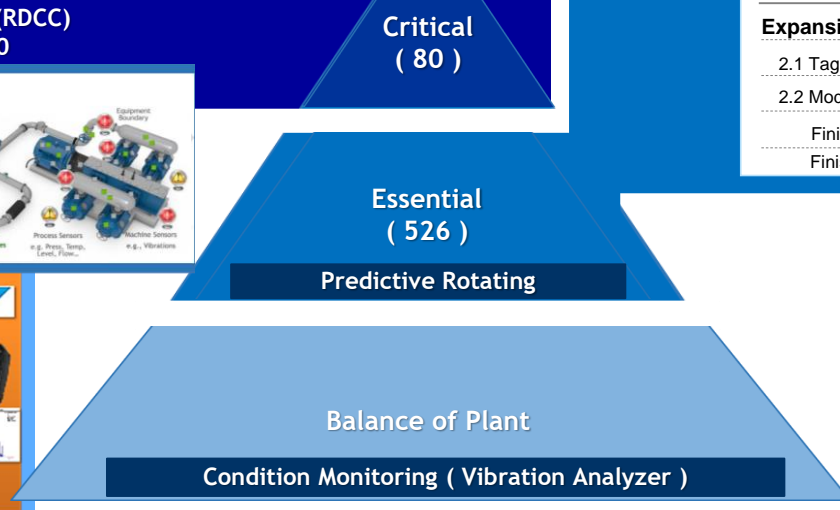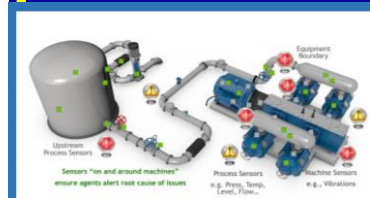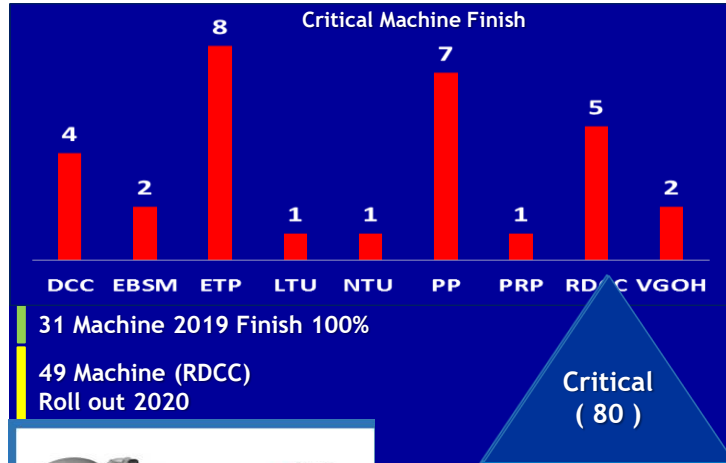| High margin lost	12
T/A cycle extension	8

Machine selection concept Bad actor DEM case IRPC unplanned Shutdown high margin lost and critical machine impact T/A Cycle extension.
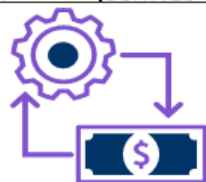
Principal Predictive maintenance

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Self Implement : 2020-2021

Action plan 2020 **S2** Reliability and Asset Integrity **O1** *Equipment Integrity*

❑ **Digital & Technology:** **Rotating Predictive Maintenance**

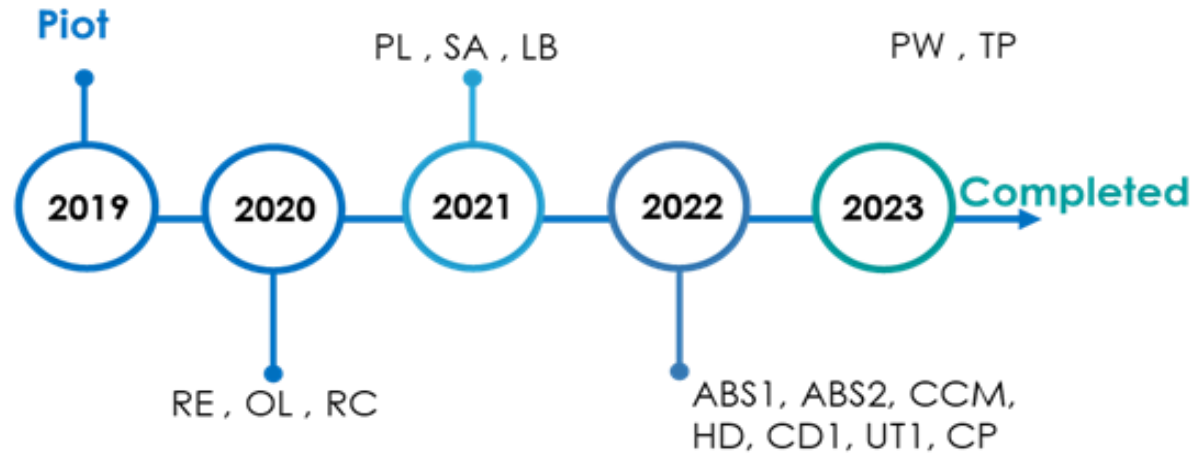**Critical Machine Finish**

Machine	Count
DCC	4
EBSM	2
ETP	8
LTU	1
NTU	1
PP	7
PRP	1
RDCC	5
VGOH	2

31 Machine 2019 Finish 100%

49 Machine (RDCC) Roll out 2020

Critical (80)

Essential (526)
Predictive Rotating

Balance of Plant
Condition Monitoring (Vibration Analyzer)

Plan SAP
Do
Analysis
Report

Workplan and KPIs

The Way Forward 2020-2021

Activity	2020	2021
Predictive Rotating		
1. Critical Rotating Machine		
1.1 Daily monitoring of rotating machine condition.		
1.2 Create new failure model when machine shutdown.		
1.3 Internal know how development on critical rotating machines failure. (Team learning)		
1.4 Decision making required when early warning comes out.		
Expansion Rotating 526 Machine 2020-2024		
2.1 Tag List Selection & Data Historian		
2.2 Model Building Early Detect Anomalies		
Finish 267 Machine 2020		
Finish 308 Machine 2021		

267   308
2020   2021

P   P   P

Detects Inappropriate Upstream Operation — Do No Harm

Alert Early — Avoid extreme damage

No Damage — Avoid the unplanned maintenance ... completely

Successfully detected all unplanned events.

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Self Implement : 2022-2023

Piot

PL , SA , LB

PW , TP

2019 — 2020 — 2021 — 2022 — 2023 → Completed
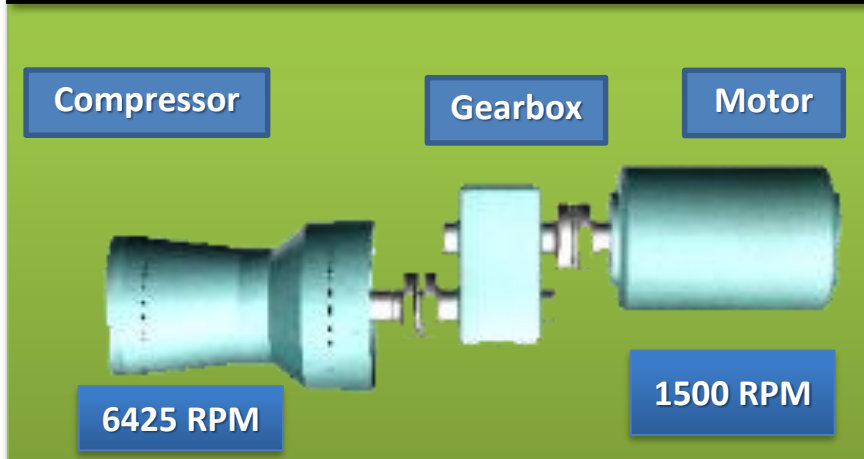
RE , OL , RC

ABS1, ABS2, CCM, HD, CD1, UT1, CP

2022 Implement Machine Learning Model 139 Eq Area ABS1, ABS2, CCM, HD, CD1, UT1, CP

2023 Implement Machine Learning Model 120 Eq Area Complex PW, TP MA AI iPredict platform

Bearing vibration: TOO LATE

Much Earlier Detection

Extra Lead Time

To Make Good Decisions

Current Solutions Short Lead-time

temporal, multi-variate signals across time & many sensors
humans cannot do this

Detects Inappropriate Upstream Operation
Do No Harm

Alert Early
Avoid extreme damage

No Damage
Avoid the unplanned maintenance ... completely

Monitoring: Wet Gas Compressor 31K002 DCC Plant

Failure and Anomaly Prediction Live Monitoring Data Every 1 Hr.

Machine Learning Agent	Latest Result	Probability Date	Alert Probability
Axial Vibration Motor - Failure Agent - [D...	Normal	05/19/2022 10:23:48 AM	
Lube Oil Loss Efficiency - Failure Agent -...	Normal	05/19/2022 10:23:48 AM	
Process-Anomaly Agent - 31K002	Normal	05/19/2022 10:23:48 AM	
Motor Valve- SG: VALVE - Failure Agent ...	Normal	05/19/2022 10:23:48 AM	
Vibration Compressure Drive End Proble...	Normal	05/19/2022 10:23:48 AM	
Vibration Bearing Compressor Non Driv...	Normal	05/19/2022 10:23:48 AM	
Axial Trust Bearing Sensor Problem - An...	Normal	05/19/2022 10:23:48 AM	
Bearing Compressor Vibration Problem	Normal	05/19/2022 10:23:48 AM	
Bearing Gearbox Vibration Problem	Normal	05/19/2022 10:23:48 AM	
Asset Performance	Normal	05/19/2022 10:23:48 AM	
Motor Problem - Anomaly Detector - DC...	Normal	05/19/2022 10:23:48 AM	
Compressor Problem V1 - Anomaly Dete...	Normal	05/19/2022 10:23:48 AM	
Lube Oil Loss of Efficiency - Anomaly De...	Normal	12/04/2020 8:18:57 AM	
Gearbox Problem	Normal	05/19/2022 10:23:48 AM	
Vibration Sensor Problem - Anomaly Det...	Normal	05/19/2022 10:23:48 AM	

Compressor   **Gearbox**   **Motor**

6425 RPM   **1500 RPM**

PROJECT UNIT
WET GAS COMP DRESSOR-RAND 3MW8-6

Discharges ST1 4.36 Bar   **Discharges ST2 16.7 Bar**

Monitoring: Top Gas Compressor 40K010 PP Plant
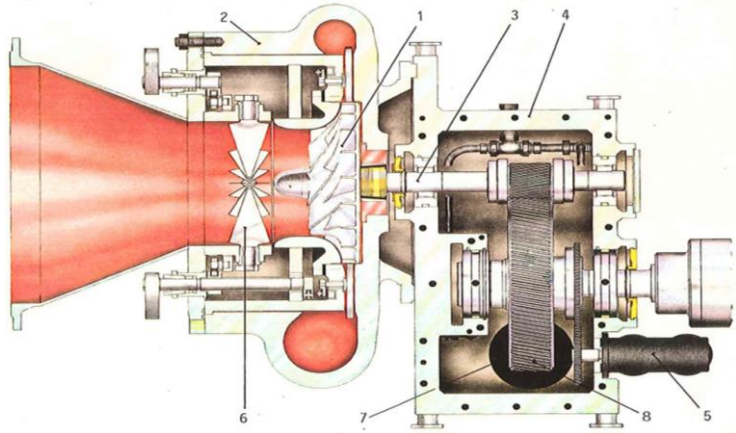
▶ Failure and Anomaly Prediction Live Monitoring Data Every 1 Hr.			
Machine Learning Agent	**Latest Result**	**Probability Date**	**Alert Probability**
Lube Oil Loss Efficiency - Failure Agent -...	Normal	05/19/2022 10:23:48 AM	
Lube Oil Gearbox and Motor Problem - ...	Normal	05/19/2022 10:23:48 AM	
Lube Oil Temp Gearbox and Motor Probl...	Normal	05/19/2022 10:23:48 AM	
40K010 - Anomaly Detector - MOTOR	Normal	05/19/2022 10:23:48 AM	▮
40K010 - Anomaly Detector - GB/MOTO...	Normal	05/19/2022 10:23:48 AM	▮
Compressor Process Problem - Anomaly...	Normal	05/19/2022 10:23:48 AM	▮▮
40C010 Process Problem - Anomaly Det...	Normal	05/19/2022 10:23:48 AM	▮▮▮
40K010-SG: Winding Temp-Anomaly Ag...	Normal	05/19/2022 10:23:48 AM	▮▮▮▮
40D011 Process Problem - Anomaly Det...	Normal	05/19/2022 10:23:48 AM	▮▮▮▮

Top Gas Compressor	**Motor 2500 kw**	**Gear Box**	**Compressor**

Predictive Rotating : Dahsboard Status

		154	88		

Complex PL | Complex SA | Complex RE | Complex OL | Complex LB | Complex RC | Complex TABS | Complex PW | Complex TP

154 | 88 | 112 112 | 88 88 | 83 82 | 48 38 | 73 73 | 103 30 | 51 0 | 69 0

62	0	3	0	0	0	8	0	12	12	5	5	8	8	5	5	0	0	0	0	0	0	0	0	126	349
ABS1		ABS2		ABS4		CCM		EPS		SAN1		SAN2		SAN3		ABS6		PPDS		ABS3		PPDT	SASB	All Equipments Related	All Sensors Monitoring

Item	Complex	Plant	Machine	Equipment	Type	Unit Opportunity Loss	Tag Mapping By	Tag View	Import By	Tag Mapping	Excel Template	Import Dataset	Model Created	Model Type	Status
1	Complex TABS	SAN2	30P001A-P01	SAN2-30P001A-P01	VERTRICAL PUMP	Unit30	Pichet Jasrichai	View	Pichet Jasrichai	Finish	Finish	Finish	Finish	Machine-Process	Complete
2	Complex TABS	SAN2	30P001B-P01	SAN2-30P001B-P01	VERTRICAL PUMP	Unit30	Pichet Jasrichai		Pichet Jasrichai	Finish	Finish	Finish	Finish	Machine-Process	Complete
3	Complex TABS	SAN2	30P001C-P01	SAN2-30P001C-P01	VERTRICAL PUMP	Unit30	Pichet Jasrichai		Pichet Jasrichai	Finish	Finish	Finish	Finish	Machine-Process	Complete
4	Complex TABS	SAN2	32N201	SAN2-32N201-RN01	AGITATOR	Unit32	Theerayut Phonrut	View	Theerayut Phonrut	Finish	Finish	Finish	Finish	Process	Complete
5	Complex TABS	SAN2	35K501-C01	SAN2-35K501-C01	SCREW COMPRESSOR	Unit35	Piya Sanewong Na Ayutthay	View	Piya Sanewong Na Ayutthay	Finish	Finish	Finish	Finish	Machine-Process	Complete
6	Complex TABS	SAN2	37A701-A01	SAN2-37A701-A01	SCREW COMPRESSOR	Unit37		View	Sombat Bangkaew	Finish	Finish	Finish	Finish	Machine-Process	Complete
7	Complex TABS	SAN2	37A701-C01	SAN2-37A701-C01		Unit37			Sombat Bangkaew	Finish	Finish	Finish	Finish	Machine-Process	Complete
8	Complex TABS	SAN2	38A801	SAN2-38A801-A01		Unit38	Somchai Vonglikit	View	Somchai Vonglikit	Finish	Finish	Finish	Finish	Machine-Process	Complete

Predictive Rotating : Alert Case Report 2019-2022

Predictive Rotating Alert Dashboard ⚠ Alert 58 🏳 Closed 38

1	0	3	4	0	7	0	0	0
Complex PL	Complex SA	Complex RE	Complex OL	Complex LB	Complex RC	Complex TABS	Complex PW	Complex TP

## IRPC 4.0 O4-Predictive Rotating Success Case Complex TABS

Item	Alert Date	Plant	Machine	Alert Name	Failure Mode	WorkOrder	Maintenance Cost (Baht)	Report By	Alert Status
1	4/10/2020 11:54:00 PM	SAN2	32N201	[SAN2-32N201-RN01] - Failure Agent - Fouling Problem 20 Days				Theerayut Phonrut	Closed
2	08/01/2022 3:00:00 AM	SAN2	30P001A-P01	Cooling Tower Sensor Problem - Anomaly Detector - SAN2-30C001A-C01				Pichet Jasrichai	Closed
3	15/3/2022 12:31:00 PM	SAN3	47A701A	[SAN3-47A701A-C01] - Anomaly Detector - Compressor Sensor Problem				Charnyuth Anukul	Closed

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Inspection Highlight: Wet Gas Compressor

Topic/ Content : DCC-31K002 Gearbox Problem - Anomaly Detector

Area : DCC
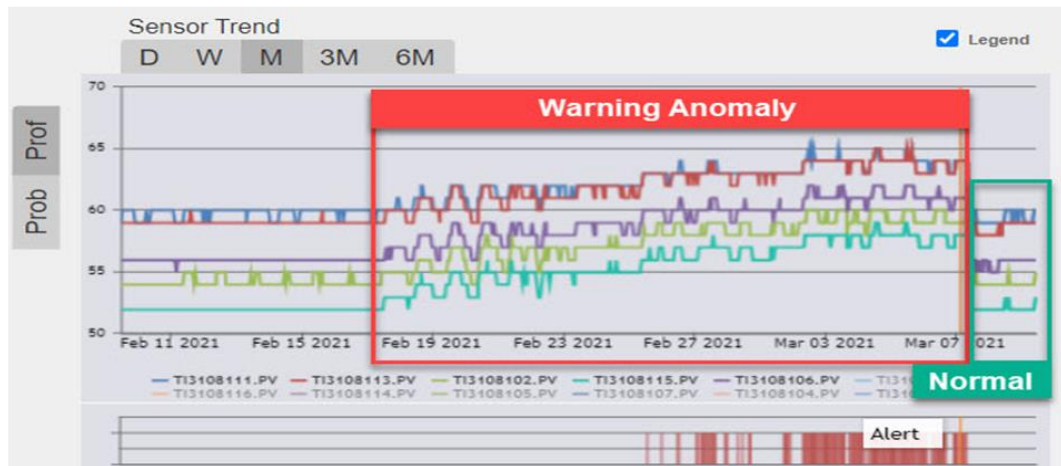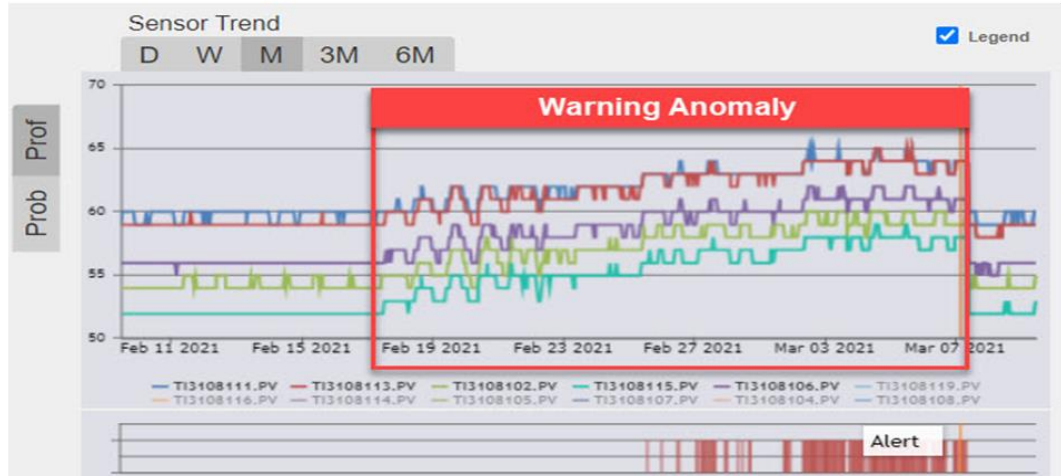
Summary

Detail : 31K002 WET GAS COMPRESSOR DRESSOR-RAND 3MW8-6
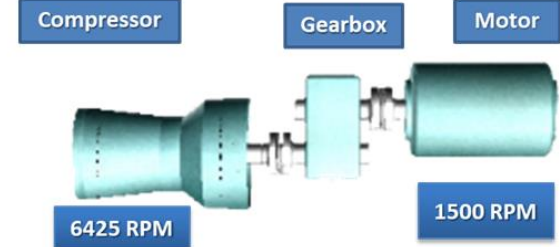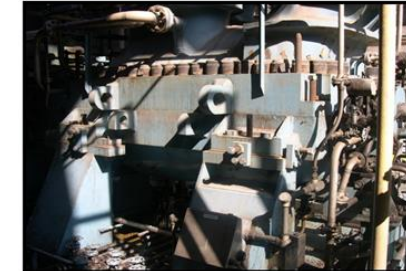
Root Cause / Possible Cause : Oil Cooler Loss of Efficiency
4 March 2021 3:02:00 PM Found temperature gearbox trend increase
-TI3108111.PV GB_DRIVER_DE_BRG_MTL_TEMP_1
-TI3108113.PV GB_DRIVER_NDE_BRG_MTL_TEMP_1

Mitigation :
K. Prasopchock Wiwek Plant DCC corrective action Program Prediction Sensor Anomaly Detection alert for Back flush cooler lube oil 31K002.

Gearbox temperature trend decrease from 59°C →53°C to normal operating condition.

Inspection Highlight: Top Gas Compressor

Topic/ Content : Lube Oil Loss Efficiency - Failure Agent - PP12-40K010

Area : PP
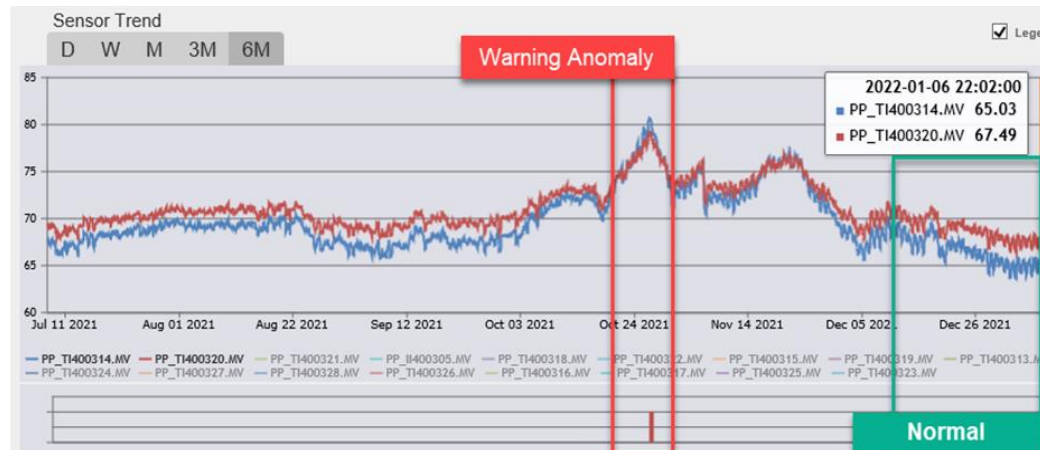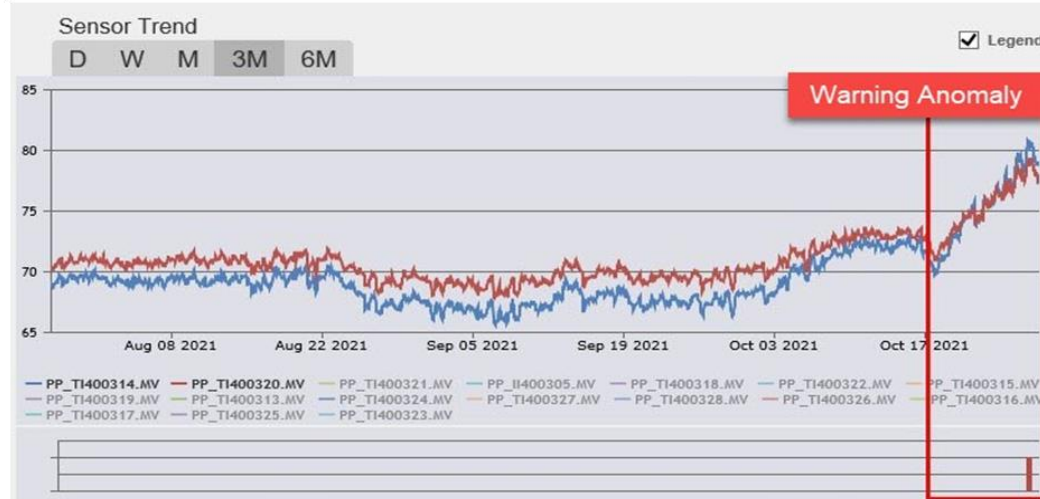
Summary

Detail : 40K010 TOP COMPRESSOR PP Plant Unit 40
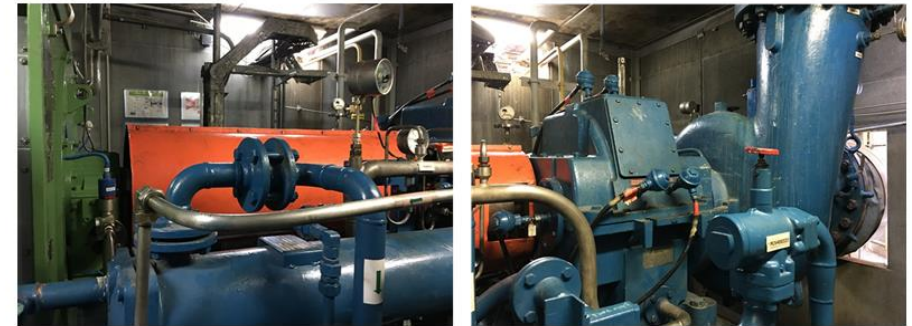
Motor Top Gas Compressor 2500 kw 3000 RPM Unit 40
Gearbox and Compressor 10434 RPM

Root Cause / Possible Cause : Oil Cooler Loss of Efficiency
26 October 2021 1:02:00 AM Found temperature gearbox trend increase
- PP_TI400314.MV GB_DRIVEN_DE_BRG_MTL_TEMP_1
- PP_TI400320.MV GB_OIL_MTL_TEMP_2

Mitigation :
Information alert to production check plant operating condition and maintenance team for check machine condition. Inspection check oil property normal and oil temperature of oil cooler B inlet 75.2°C outlet 65.8°C

-Machine can operate in normal condition. Compressor and Gear Oil temperature trend decrease to normal operating condition.

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Inspection Highlight: Blower Vibration Problem

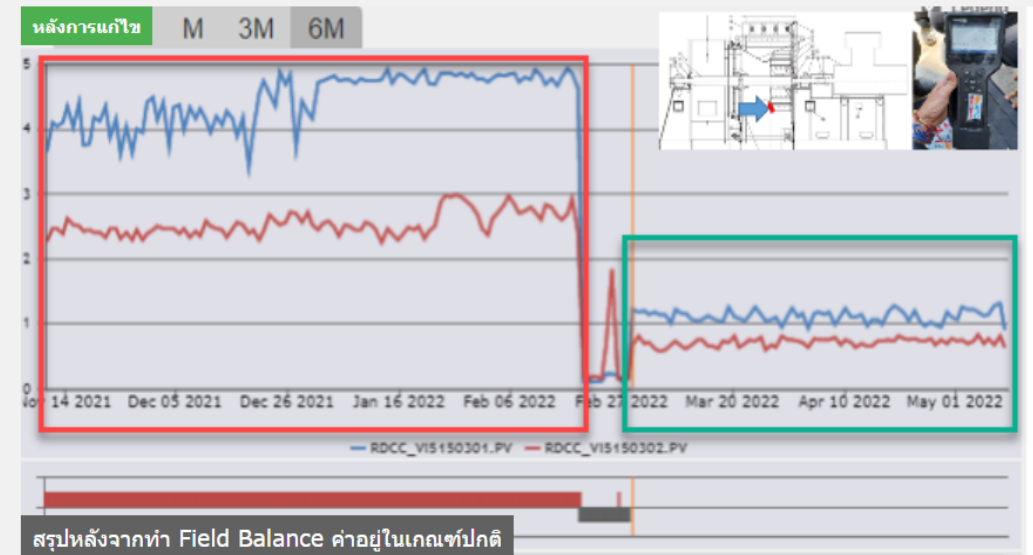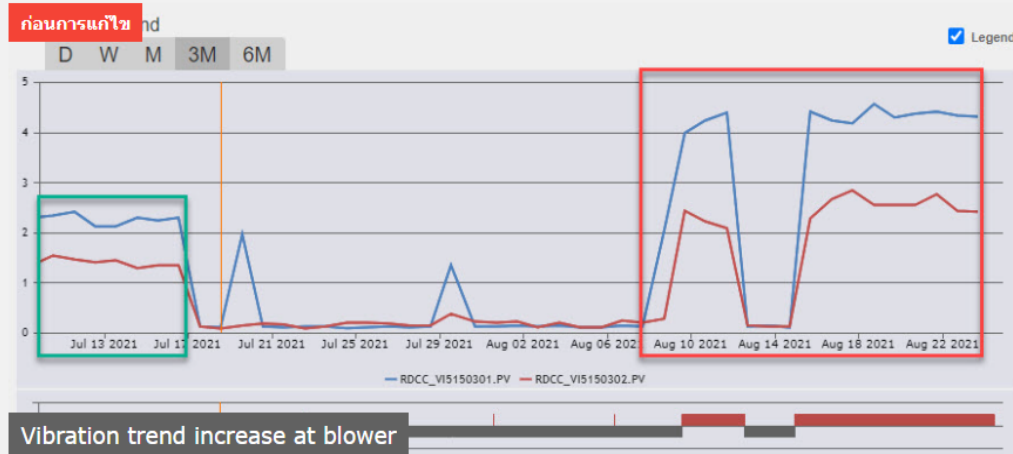**IRPC 4.0   Predictive Rotating Success Case : HSU-51K002 [HSU-51K002-K01] - Anomaly Detector - Blower Problem**   **Success Case #13**

ผลการตรวจสอบ (**Result Alert**)   Link

1/12/2021 5:12:00 PM Found vibration sensor RDCC_VI5150301.PV RDCC_VI5150302.PV of blower trend increase.

วิธีการแก้ไข (**Solutions**)   Attach File

-ดำเนินการทำ Field Balance ช่วงบ่ายวันที่ 26/2/65 -โดยใส่ Weight 2 ตำแหน่ง ตำแหน่ง ใบที่ 3 =30g 65องศาและ ใบที่ 4 =85g 98 องศา -หลังจากนั้น Start up เครื่องจักรเพื่อวัดค่า Vibration หลังทำ Balance ผลพบว่าค่า Vibration ลดลงจาก 3 mm/s เหลือ 0.49 mm/s ที่ตำแหน่ง Blower Drive End และตำแหน่ง Blower None Drive End ลดลงจาก 1.9 mm/s เหลือเพียง 0.3 mm/s -สรุปค่าอยู่ในเกณฑ์ปกติ

ก่อนการแก้ไข

Vibration trend increase at blower

หลังการแก้ไข   M   3M   6M

สรุปหลังจากทำ Field Balance ค่าอยู่ในเกณฑ์ปกติ

Inspection Highlight: Reactor Warning Fouling Problem

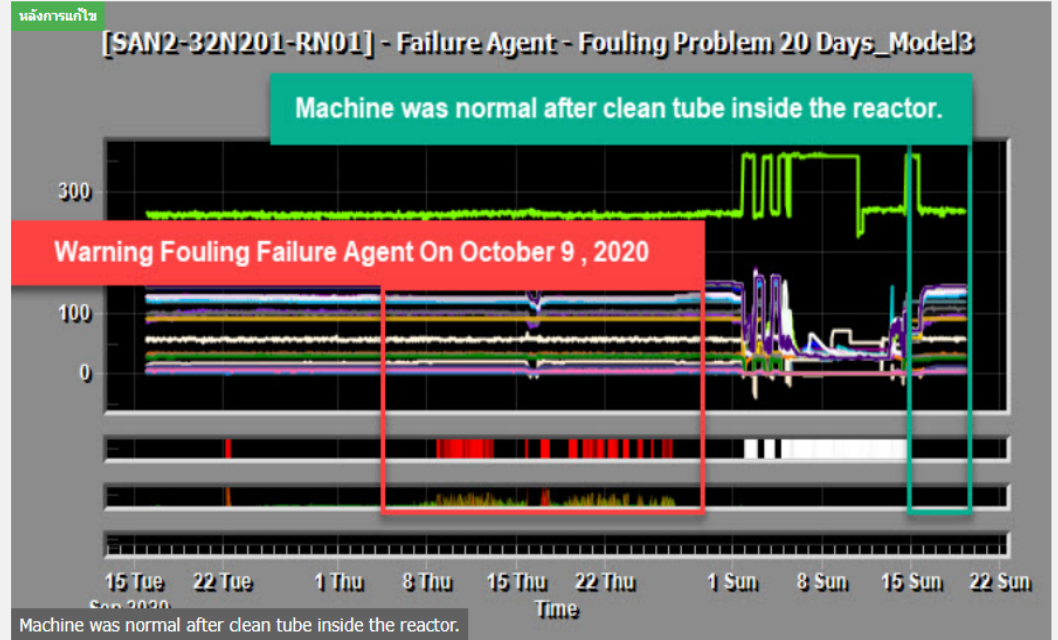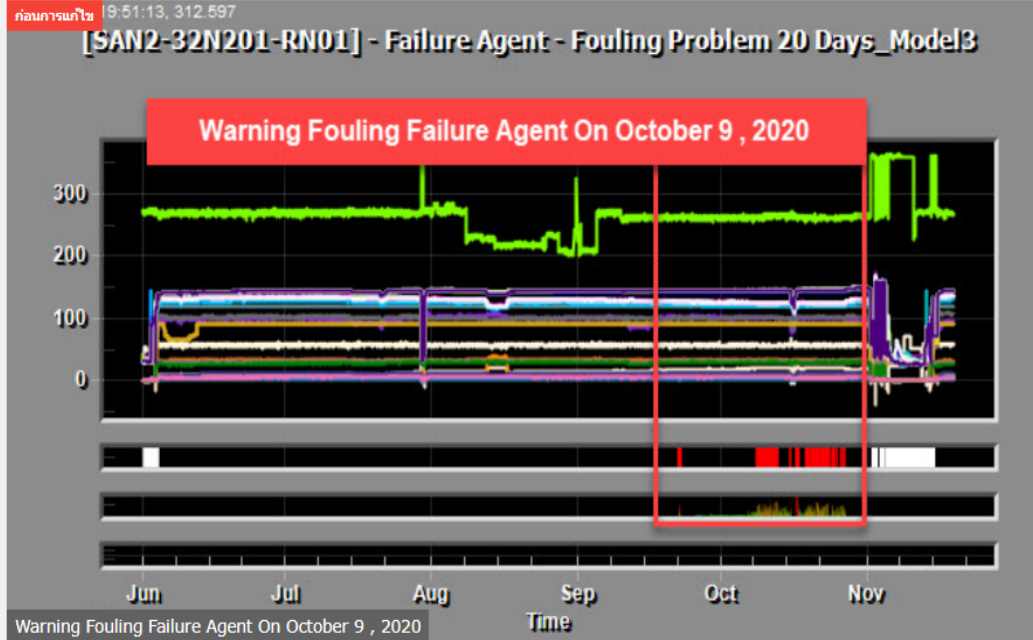IRPC 4.0   Predictive Rotating Success Case : SAN2-32N201 [SAN2-32N201-RN01] - Failure Agent - Fouling Problem 20 Days   **Success Case #1**

ผลการตรวจสอบ (Result Alert)   Link

4/10/2020 11:54:00 PM Model Process Fouling สร้างขึ้นร่วมกับ K.Wiroj Namhom โดยการ Forecast shutdown SAN2 @ Temp.diff Reactor 25 C ด้วย Model Machine Learning ซึ่งใช้ Dataset Failure On September 29 ,2019

วิธีการแก้ไข (Solutions)   Attach File

ข้อมูลจาก K.Wiroj Namhom Model forecast วันที่ 29/10/2020 Temp. diff Reactor จะขึ้นไปอยู่ที่ 25 C ขอให้เตรียม plan shutdown clean fouling ซึ่งหลังจากที่ SAN2 Shutdown เพื่อ Clean Tube Reactor หลังจาก Startup plant Temp.diff Reactor SAN1_2_TDR320101.PV trend ลดลงปกติ

[SAN2-32N201-RN01] - Failure Agent - Fouling Problem 20 Days_Model3

Warning Fouling Failure Agent On October 9 , 2020

Warning Fouling Failure Agent On October 9 , 2020

[SAN2-32N201-RN01] - Failure Agent - Fouling Problem 20 Days_Model3

Machine was normal after clean tube inside the reactor.

Warning Fouling Failure Agent On October 9 , 2020

Machine was normal after clean tube inside the reactor.

Issue By - Theerayut Phonrut   Approve By - Numpol Choonhapan   23/11/2020   Item 1

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Benefit

Loss from Equipment

Equipment	Description	Plant	2015		2016		2017		2018	
			SD day	CM Loss	SD day	CM Loss	SD day	CM Loss	SD day	CM Loss
34K001	C3 Refrigerant Compressor	DCC	0.96	8.05						
34K002	Heat Pump Compressor	DCC	0.01	4.9						
C3101	Cracked Gas Compressor	ETP	4.27	40.6	0		0.19	3.45	0.32	5.35
C4601	Propylene Compressor	ETP	0		0		1.92	38	0.85	6.25
53K101	Wet GasCompressor(w/TBN)	RDCC	0		0		0		0.47	28.3
03K001	OFF GAS COMPRESSOR	EBSM	0		1.9	9.8	0		0	
30K001A	Make up & Recycle Gas compressor	VGOH	0		0.3	2.45	0		0	
30K001B	Make up & Recycle Gas compressor	VGOH	0		0.9	3.15	0		0	
90RN10	Agitator	PP	0		0.5	4.9	0		1.04	3.64
			5.24	53.55	3.6	20.3	2.11	41.45	2.68	43.54
	Average/year			10.2195		5.63889		19.6445		16.2463

51.7492 M Baht 4 Year
12.9373 M Baht Per Year
0.40429 M US$

OPS-O4: Predictive Rotating Prevention Critical Machine Unplanned Shutdown

Benefit 12 MB Per Year

SCGC   GC   iRPC   Thaioil   TIChE

Predictive Rotating : Digital Transformation

Thank you for your attention