EDF participation to ROMEO European project
Diagnosis and Prognosis
Physical and Statistical models

Bousseau Pierre, EDF R&D

18/06/2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme
under grant agreement No 745625.

EDF Group

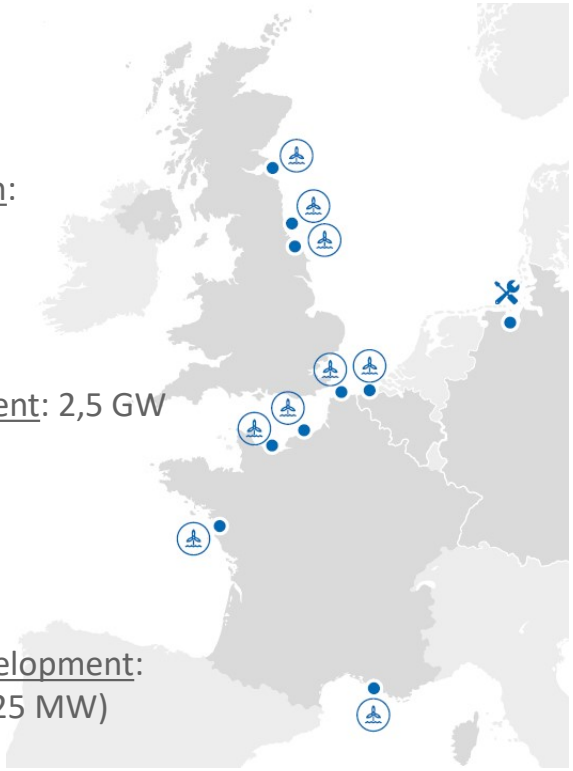
Wind Energy

Onshore: 10 GW

Offshore fix in operation:
Teesside (62MW)
Blyth (41,5 MW)
C-Power (participation)

Offshore fix in devlopment: 2,5 GW
Saint Nazaire, Fécamp
Courseulles-sur-Mer
Neart na Gaoithe
Dunkerque

Offshore floating in development:
Provence Grand Large (25 MW)

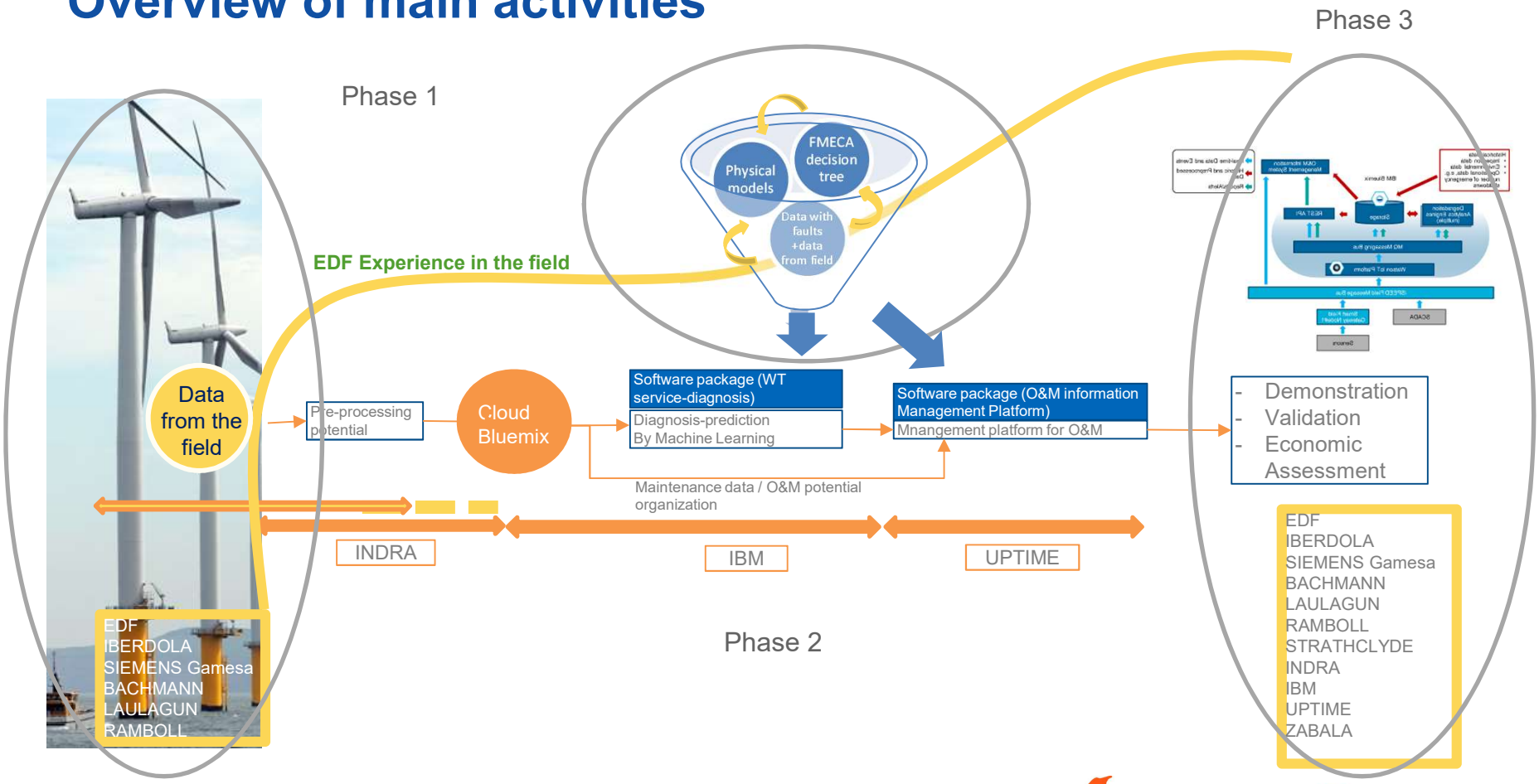


ROMEO European Project

Main objective: High LCoE reduction with development and use of reliable O&M decision tools and strategies

Main participation from EDF focused on:
- Teesside wind farm pilot site
- Participation to development of physical and statistical diagnosis & prognosis models

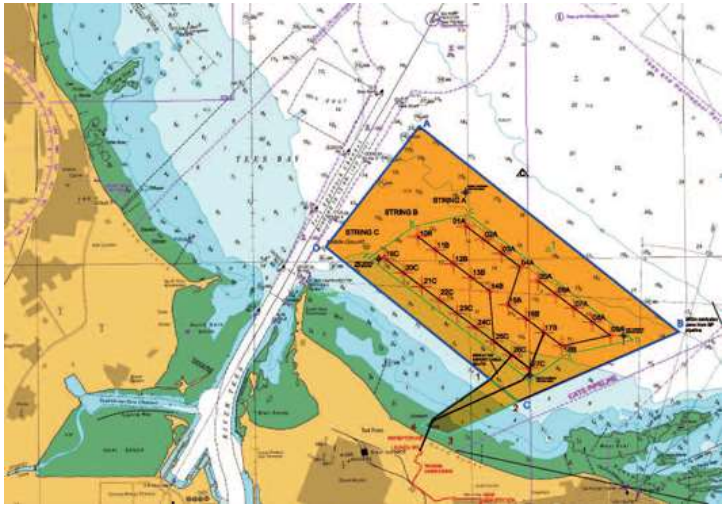
Overview of main activities



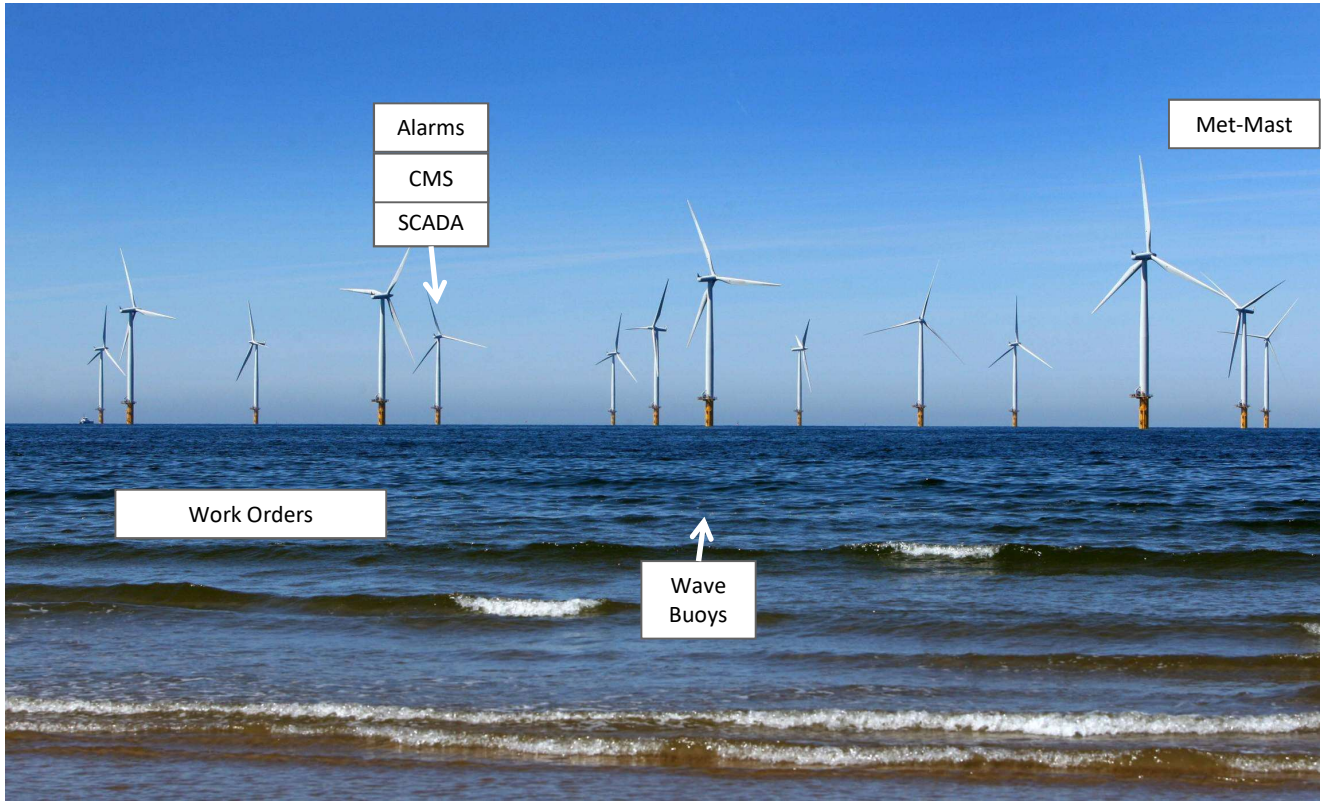
Teesside wind farm and operational data

Teesside wind farm

Localisation: Teesside - Redcar
Date of installation: 2013
Power: 62 MW
WTs: 27 x 2,3 MW Siemens, D 90m
Distance to shore : 1,5 km
Water depth: 8 to 15 m LAT
Hub height: 83 m

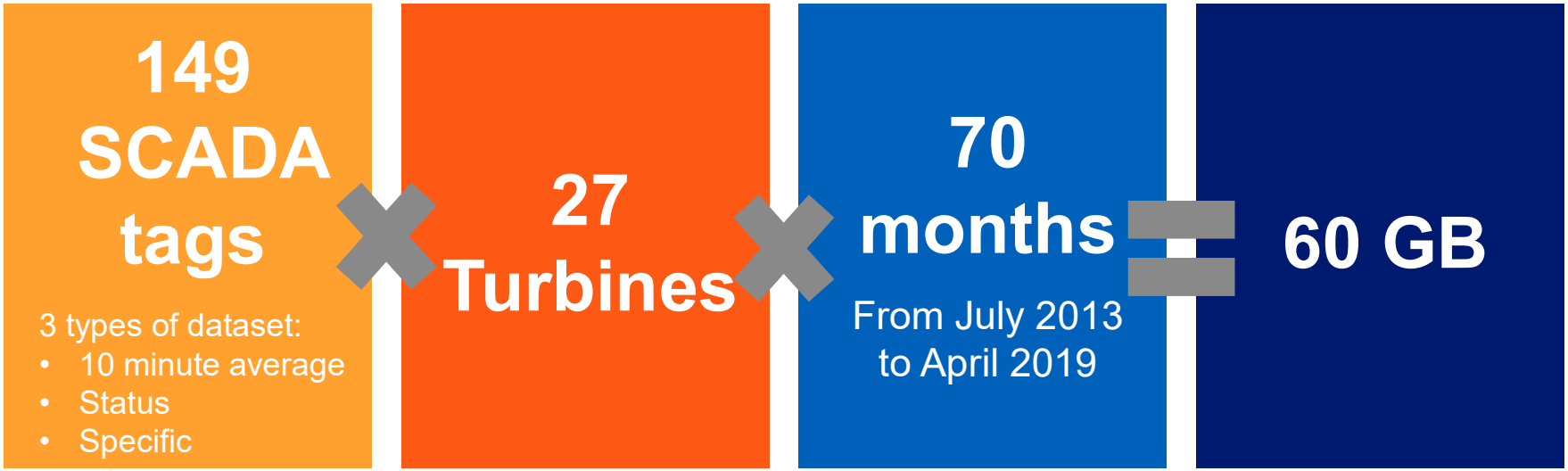


Teesside data collection



Teesside dataset downloading

SCADA Dataset



CMS Mechanical Drive Train Dataset

being received with an automatized process

Training datasets for Machine Learning – Statistical Models

Teesside dataset for training of Machine Learning

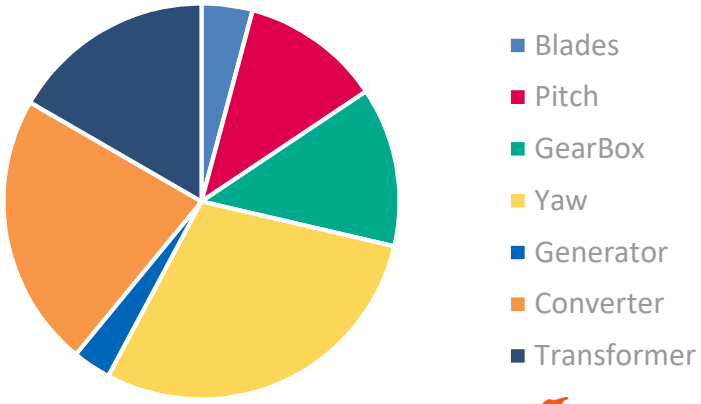
Aim: define and provide normal and abnormal datasets for training

Methodology used:

- Identification of events from Work Orders & Spare parts use
- First estimation of abnormality periods based on P-F intervals
- Refinement of the periods through expert views
- Classification: suspected, known abnormality, suspected, known normality

Overview of results:

193 events selected



Teesside dataset for training of Machine Learning

Labelling of events & periods:

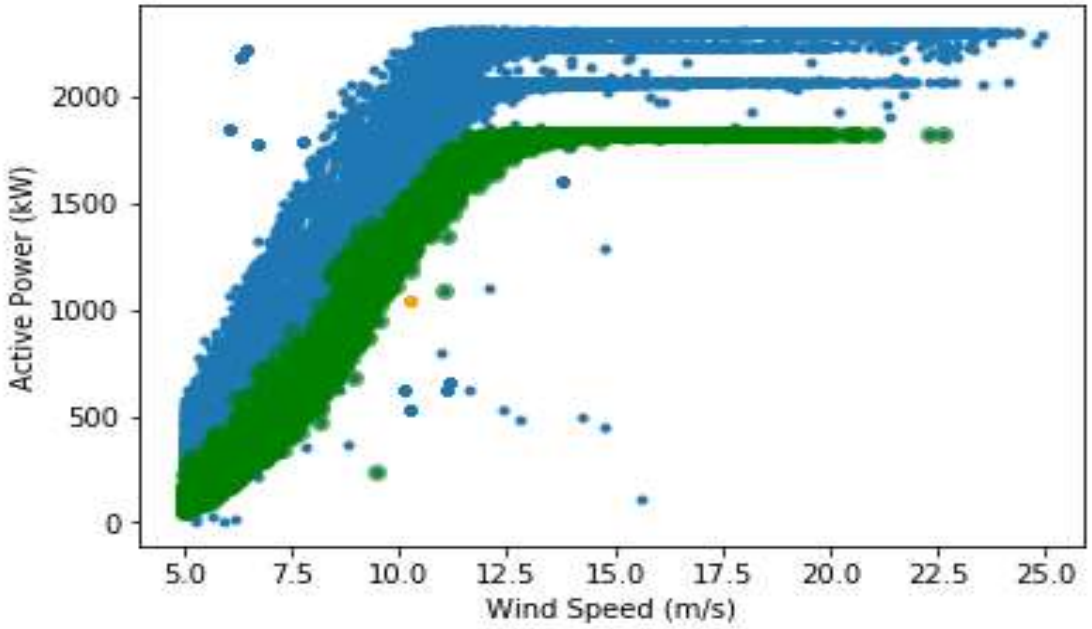
System description	Site Name	Site name
	Turbine Name	Turbine name
	Turbine Number	Turbine number
	Component	Component name
Maintenance action	Order Number	Work order number
	Order Description	Description of the maintenance work
	Order Type	Corrective
	Type of work	Replacement or Repair
	Start Date	Start date of the maintenance work
	Sensor	Maintenance action relative to the sensor: Y, N, or Unknown
AbN periods from P-F intervals	Est. Start Date	Estimated start date for the suspected or known abnormality - P-F
	Est. End Date	Estimated End date for the suspected or known abnormality
AbN periods from expert view	Est. Start Date	Esti. start date for the suspected or known abnormality - expert view
	Est. End Date	Esti. end date for the suspected or known abnormality - expert view
	Confidence Level	Medium or high, level of confidence on the failure and the possibility to detect it with data - expert view
	Degree of Abnormality	Known / Suspected abnormality / Suspected / known normality - expert view

EDF ROMEO

Teesside dataset for training of Machine Learning

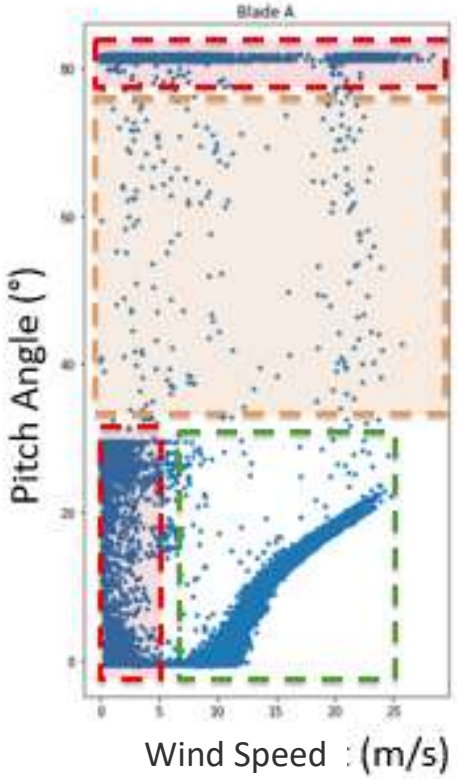
Refinement of the periods with expert view:

Identification of periods with curtailments by WT
(during first year of operation)

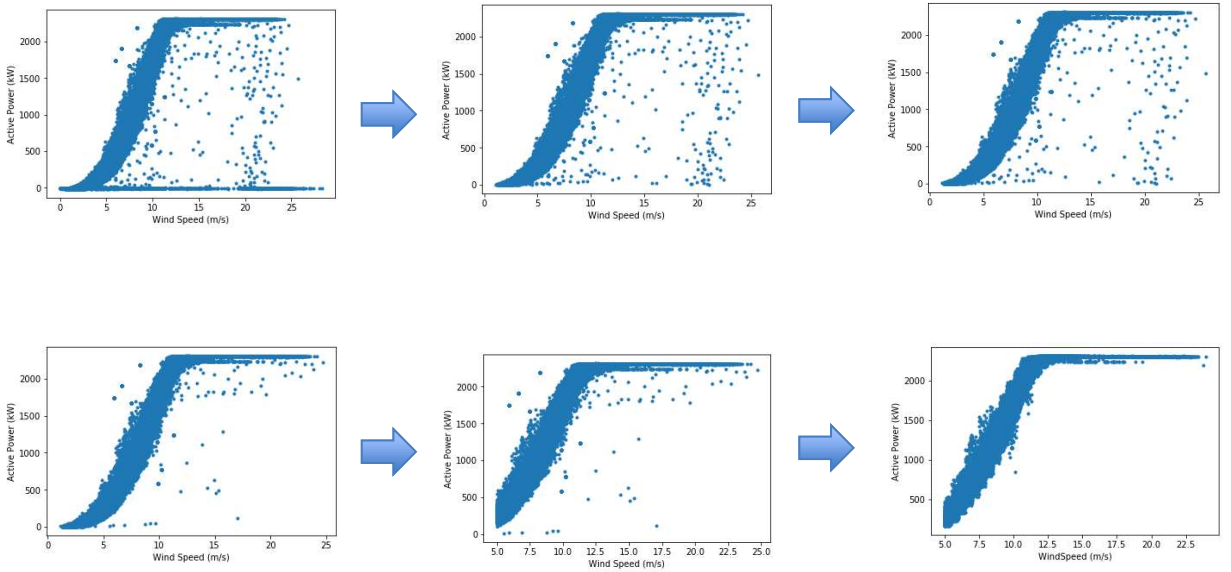


Teesside dataset for training of Machine Learning

Filtering can be needed – component – Failure mode dependent – expert view: pitch system



Example of filtering process



Physical Diagnosis & Prognosis Models - Teesside

Physical Diagnosis & Prognosis Models - Teesside

Platform B: Teesside Wind Farm – Siemens SWT2.3 (operated by EDF)

FMECA

P-F intervals for main failure modes

Available Data

Module	Description
1	Main bearing: failure early detection
2	Pitch system: failure early detection
3	Gearbox: failure early detection
4	Transformer : interturn short-circuit or Cooling System
5	Generator: Interturn short-circuit of windings, rotor bars
6	Generator: Interturn short-circuit of windings, rotor bars & cooling system

State: Normal / Abnormal

Phase of P-F interval

Temporal evolution of physical error

Time to failure prediction

EDF ROMEO

Physical Diagnosis & Prognosis Models – Teesside Electrical drive train

Generator :

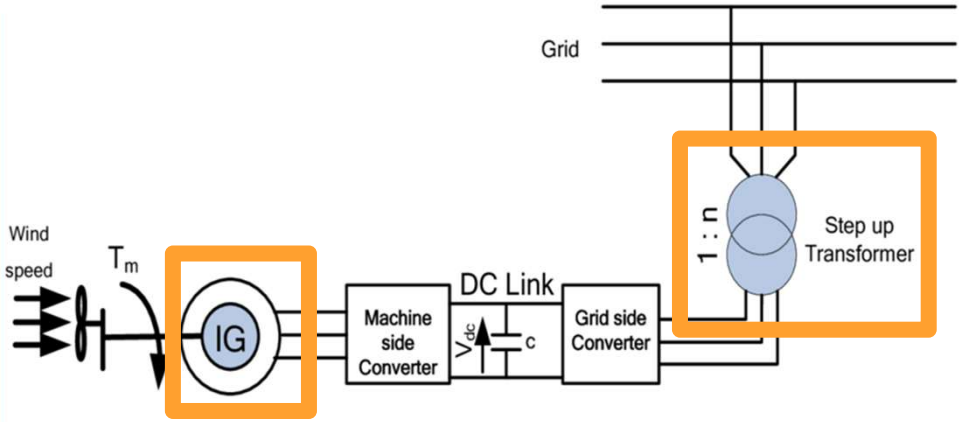
ABB 2.3 MW squirrel cage induction generator

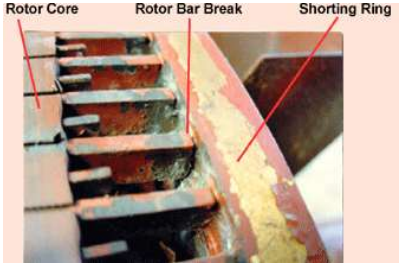
- Stator winding faults
- Rotor broken bars
- Cooling faults

Transformer:

CG Power Systems 2.6 MVA oil cooled transformer (690 V / 33 kV)

- Winding faults
- Cooling faults





Physical Diagnosis & Prognosis Models – Teesside
Electrical drive train - Generator

Thermo Electrical diagnosis:

Operational data:

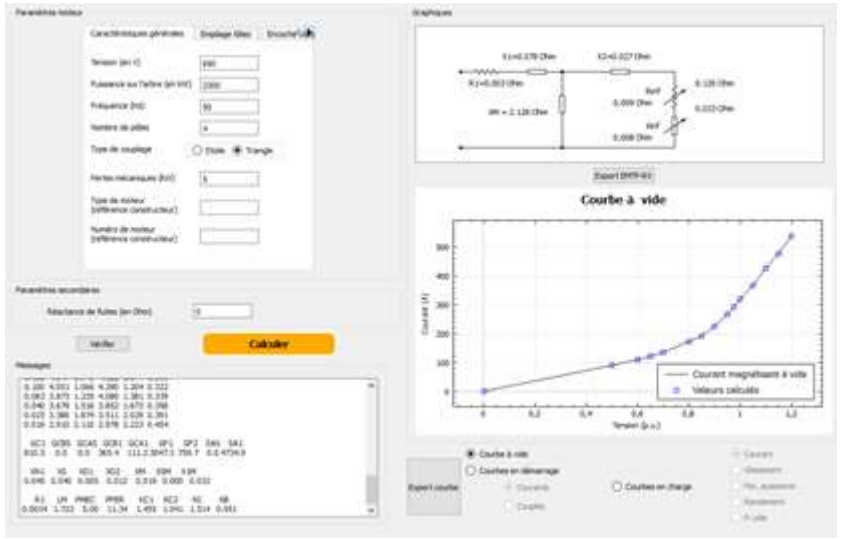
10min SCADA data, and high sampling generator currents, voltages (10kHz) and speed (2 Hz)

Generator parameters:

Generator parameters are calculated using analytical tools with generator datasheets and main dimensions of the magnetic circuit.

Setting up & use:

- Algorithm setting up and pre validation using generator models with stator and rotor faults
- Operational high sampling data not available today at Teesside ➔ use of a downgraded version



Physical Diagnosis & Prognosis Models – Teesside Electrical drive train - Generator

Generator detailed model:

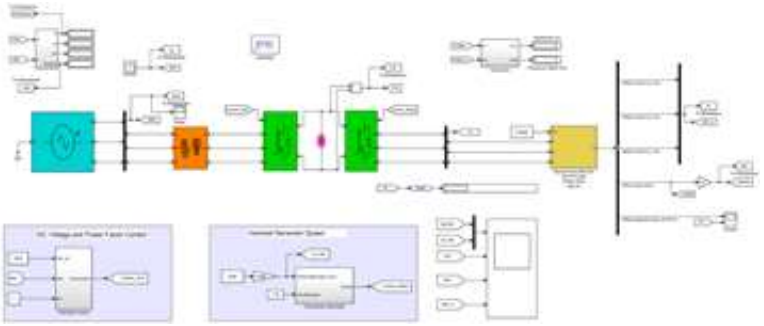
Model validation using constructor and SCADA measurements

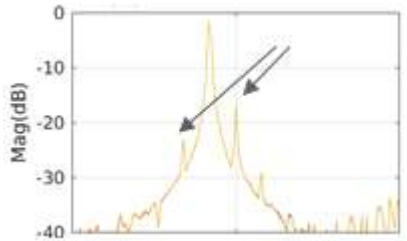
- Simulations with stator inter-turn short-circuit faults and rotor broken bars

Thermo Electrical diagnosis results:

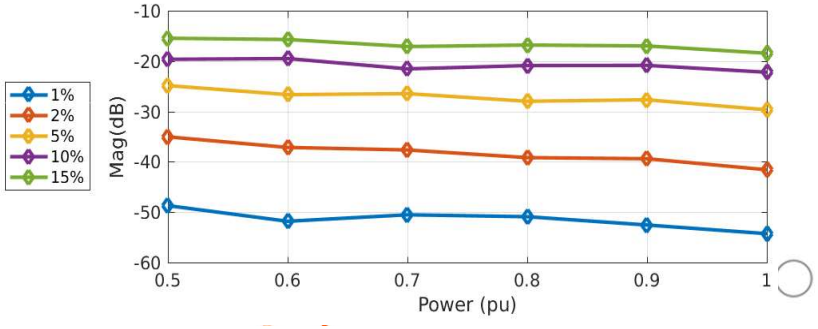
Fault detection using generator temperature, current frequency spectrum

- Winding faults (1-15% inter-turn short circuit in one coil) at different generator power
- 1-2 rotor broken bars at different generator power





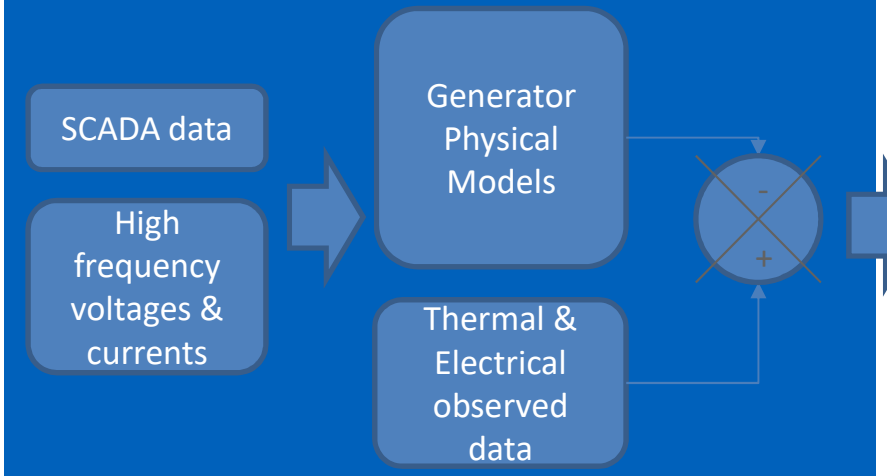
Stator freq (Hz)

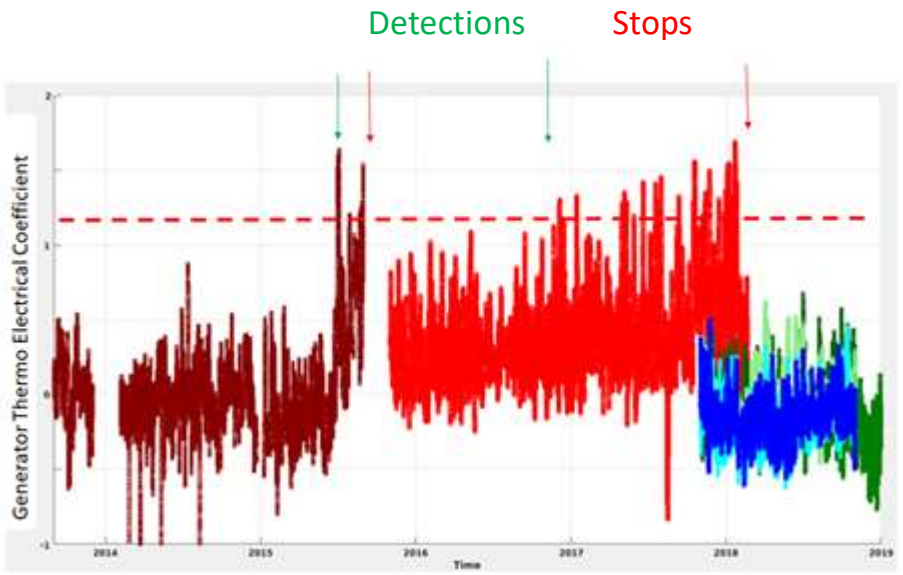


Physical Diagnosis & Prognosis Models – Teesside
Electrical drive train - Generator

Use and pre – validation

Onshore due to lack of events & data





Physical Diagnosis & Prognosis Models – New Turbines

Physical Diagnosis & Prognosis Models – New turbines

Probematic for electrical drive train: most often

- Apparent brevity of physical mecahnisms of the degradation patterns
- Lack of adequate observability

Approach selected:

Done

- Small Scale bench Test (55kW) Adaptation For failure mode caracterisation
- Design of physical algorithms: **Generator** **Transformer** **DC Bus**
- Datasets in normal and abnormal operation
- Implementation small scale bench test and algorithms

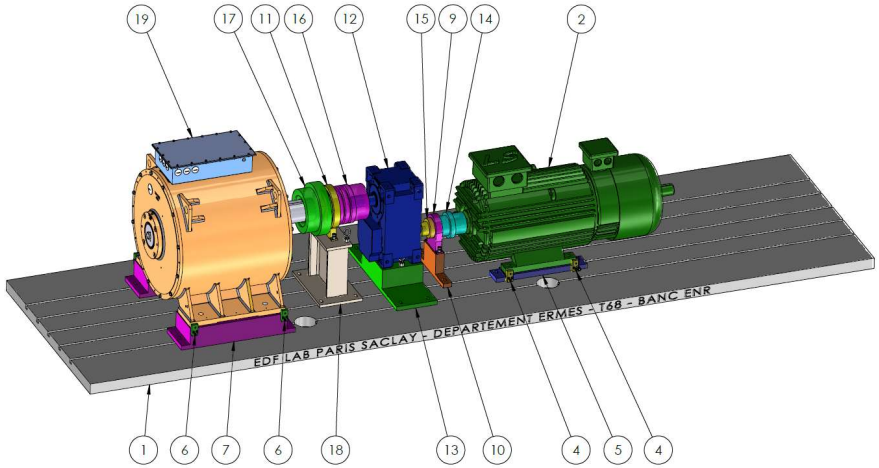
2019-2020

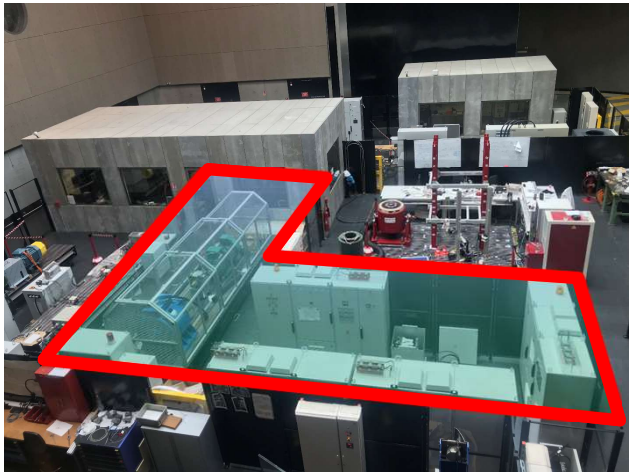
- Validation online and offline on small scale configuration
- Upscaling methodology: from small scale to full scale
- Validation full scale and portability

EDF ROMEO

Physical Diagnosis & Prognosis Models – New designs

No Article	Name	Quantity
1	Plaque ENR Bench	1
2	DBF	1
4	Fitting plates DBF	4
5	Chair DBF	2
6	Fitting plates PMSG	4
7	Chair PMSG	2
9	HBM T40B 1kN	1
10	Chair HBM T40B 1kN	1
11	HBM T40B 10kN	1
12	Gearbox BONFIGLIOLI HDP 70	1
13	Chair BONFIGLIOLI	1
14	Coupling HBM T40B 1kN DBF	1
15	Coupling HBM T40B 1kN GB	1
16	Coupling HBM T40B 10kN GB	1
17	Coupling HBM T40B 10kN PMSG	1
18	Chair HBM T40B (10kN)	1
19	PMSG	1





Physical Diagnosis & Prognosis Models – New designs

Within ROMEO: focus on the PMSG configuration

Type of faults or events generated:

- PMSG: interturn short-circuit, P-P, P-N internal faults
- DBF: stator & rotor interturn short-circuit, P-P, P-N internal faults
- Transformer: for now, fault simulation through external unbalance
- DC bus capacitor degradation
- Power electronic faults: independent control of IGBT
- Simulated grid faults: lightning shock, voltage drops, frequency variations
- Etc.

Summary & futur plans, EDF participation to ROMEO

- Physical algorithms for diagnosis & prognosis on new turbines:
  - Design of algorithms & adapted small scale bench test
  - *End of implementation for functional use during 2019*

- First framework set for use and validation of ROMEO tools on Teesside

- Teesside Physical algorithms:
  - First set of algorithms developed with initial tests on IBM cloud (5/6)
  - *Regular use, evaluation & possible improvements within the 3 following years*

- Statistical approach with machine learning
  - Identification of datasets for training material
  - *Use of the ML approach by IBM, possible improvements of the training datasets*

- *Teesside pilot test for ROMEO tools & strategies*

EDF ROMEO

Thank for your attention
Questions ?

On behalf of the team
Pierre Bousseau
Pierre.Bousseau@edf.fr

This project has received funding from the European Union's Horizon 2020 research and innovation programme
under grant agreement No 745625.