EWEA Analysis of Operating Wind Farms 2016
Spain Bilbao Apr 2016

龙源电力集团股份有限公司
CHINA LONGYUAN POWER GROUP CORPORATION LIMITED

Wind Turbine Major Components Failure Predicting Based on SCADA Data Analysis

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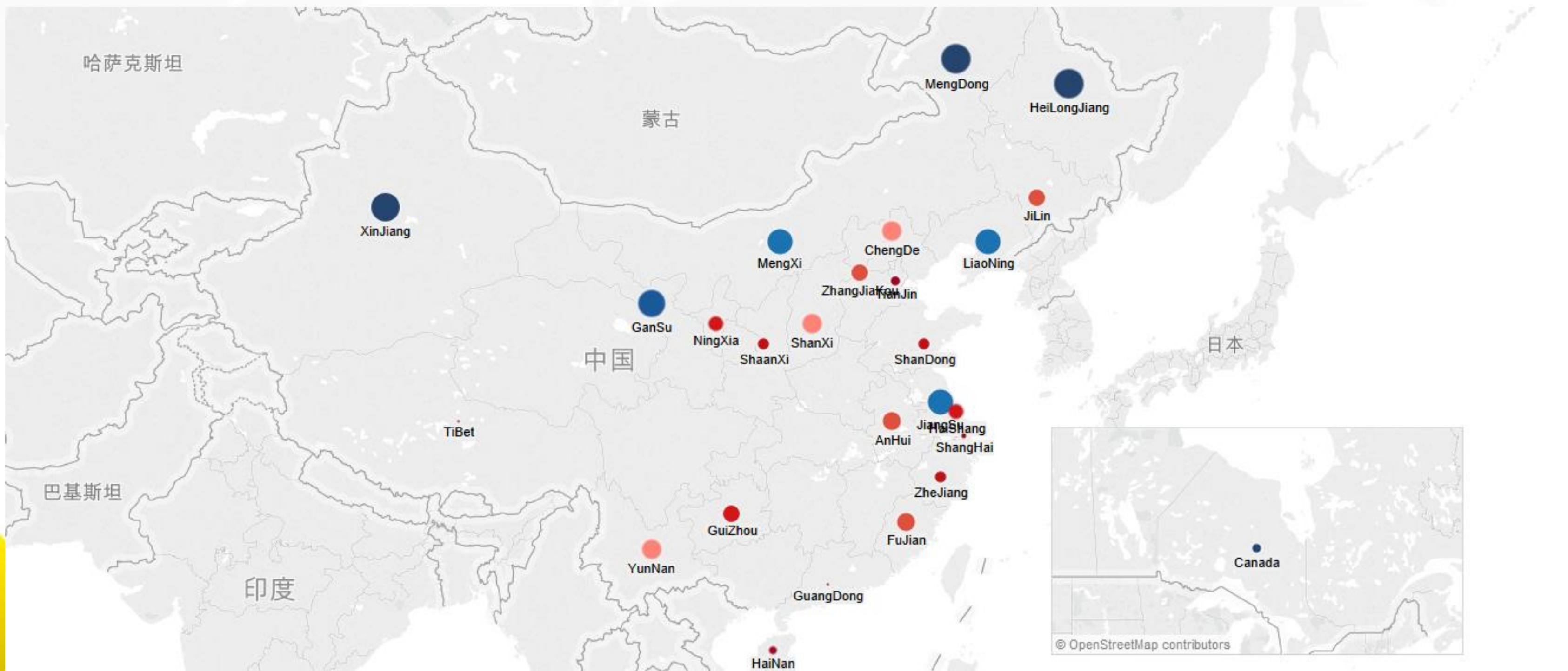
LongYuan Power Wind Energy Overview/Portfolio

>15 GW Wind Energy >11000 Wind Turbines >160Wind Farms

22 Different Turbine Manufacturers 90 Models

Investment, Design, Development, Construction, Management, O&M service.

Owner maintained more than 75% turbines in China



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What we use SCADA data for

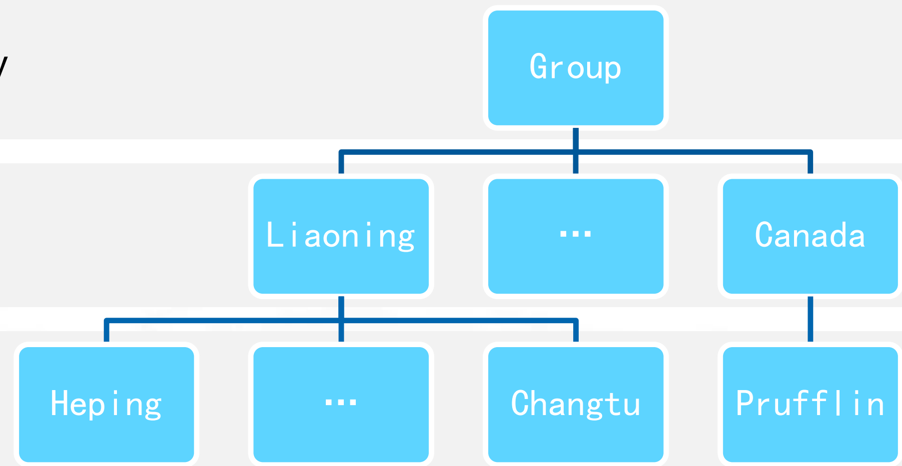
KPI

- PBA
- MTBT
- …
- MTBR

Benchmark analysis of Provincial company KPI

Benchmark analysis of wind farms KPI

Turbine by turbine analysis



Power Curve Monitoring

- Automatic classification
- Anomaly detection
- Anomaly data mining

Failure Predicting and Monitoring

- Blade
- Gearbox
- Generator
- Converter

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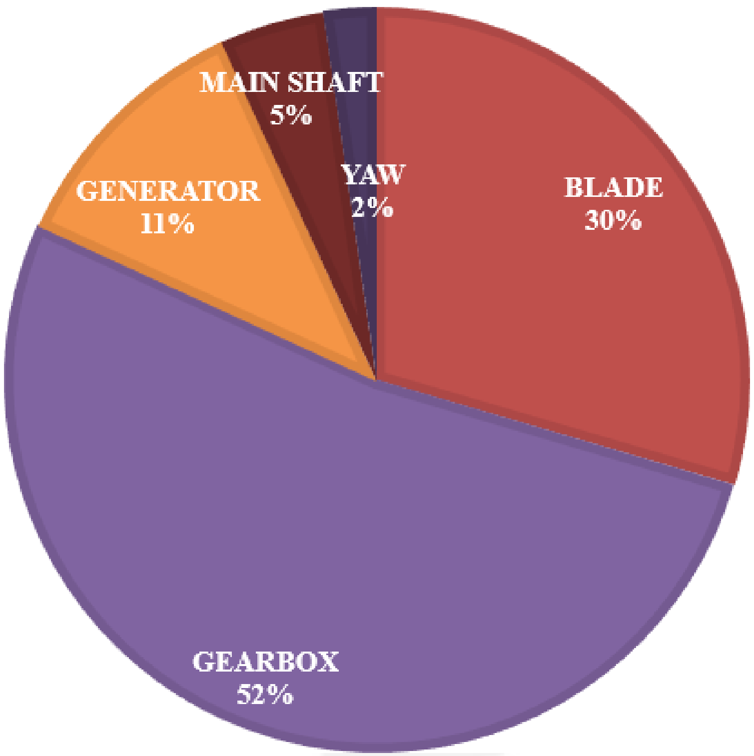
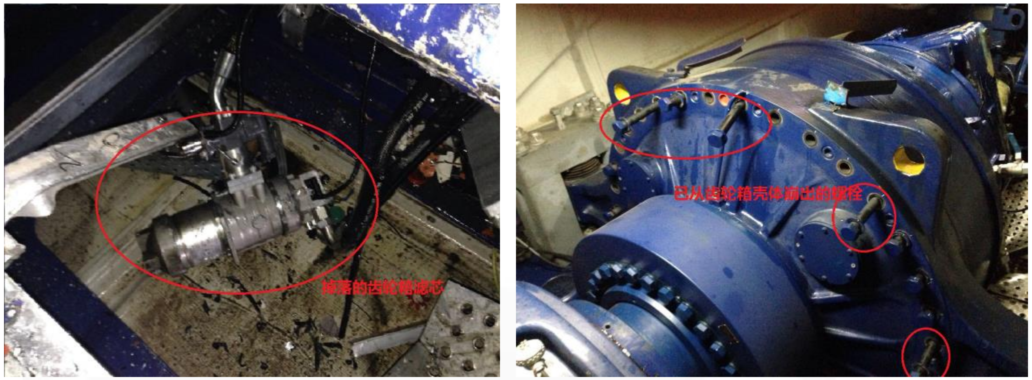
Major Component Failures in LongYuan，2015



Distribution of Major Component Failures



The damaged Gearbox

The damaged blade

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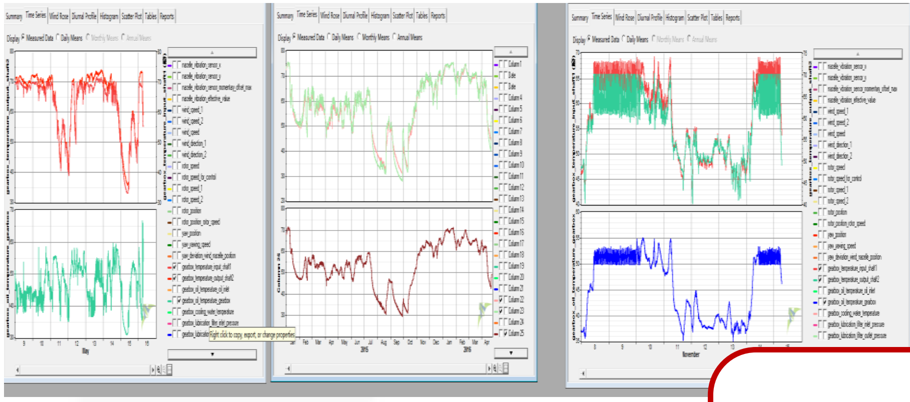
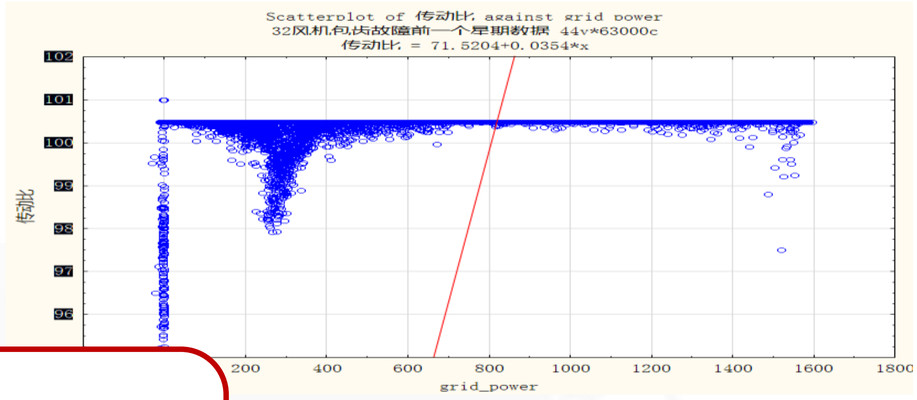
Based on the classical methods and physical rules

Time sequence of oil temperature analysis

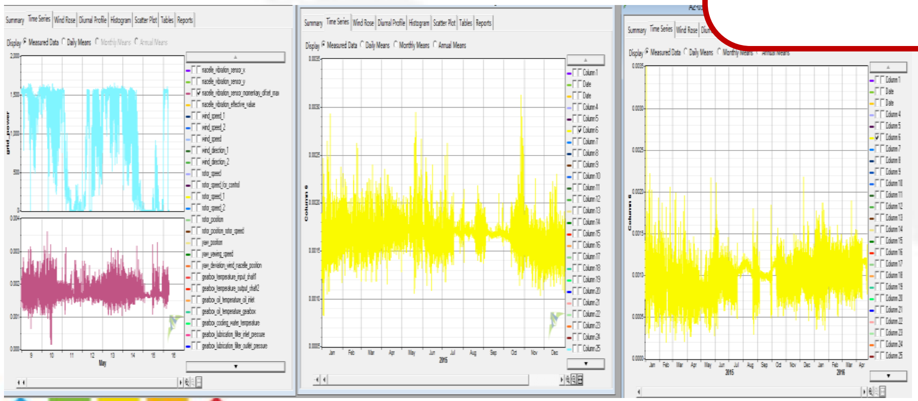


Transmission ratio analysis

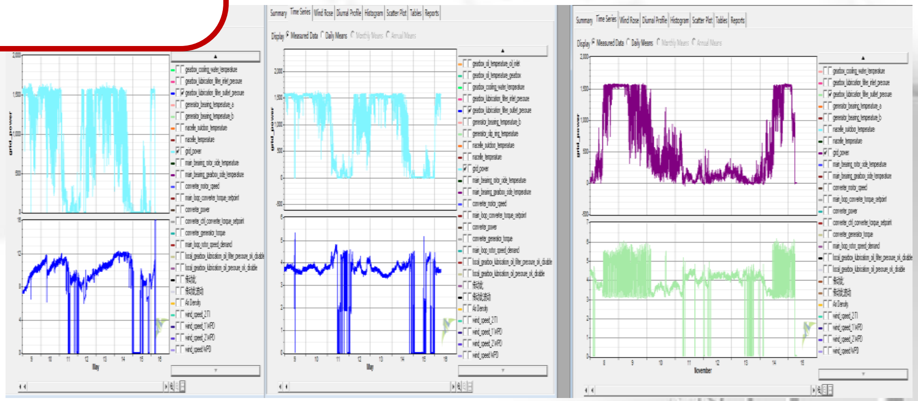


Failed

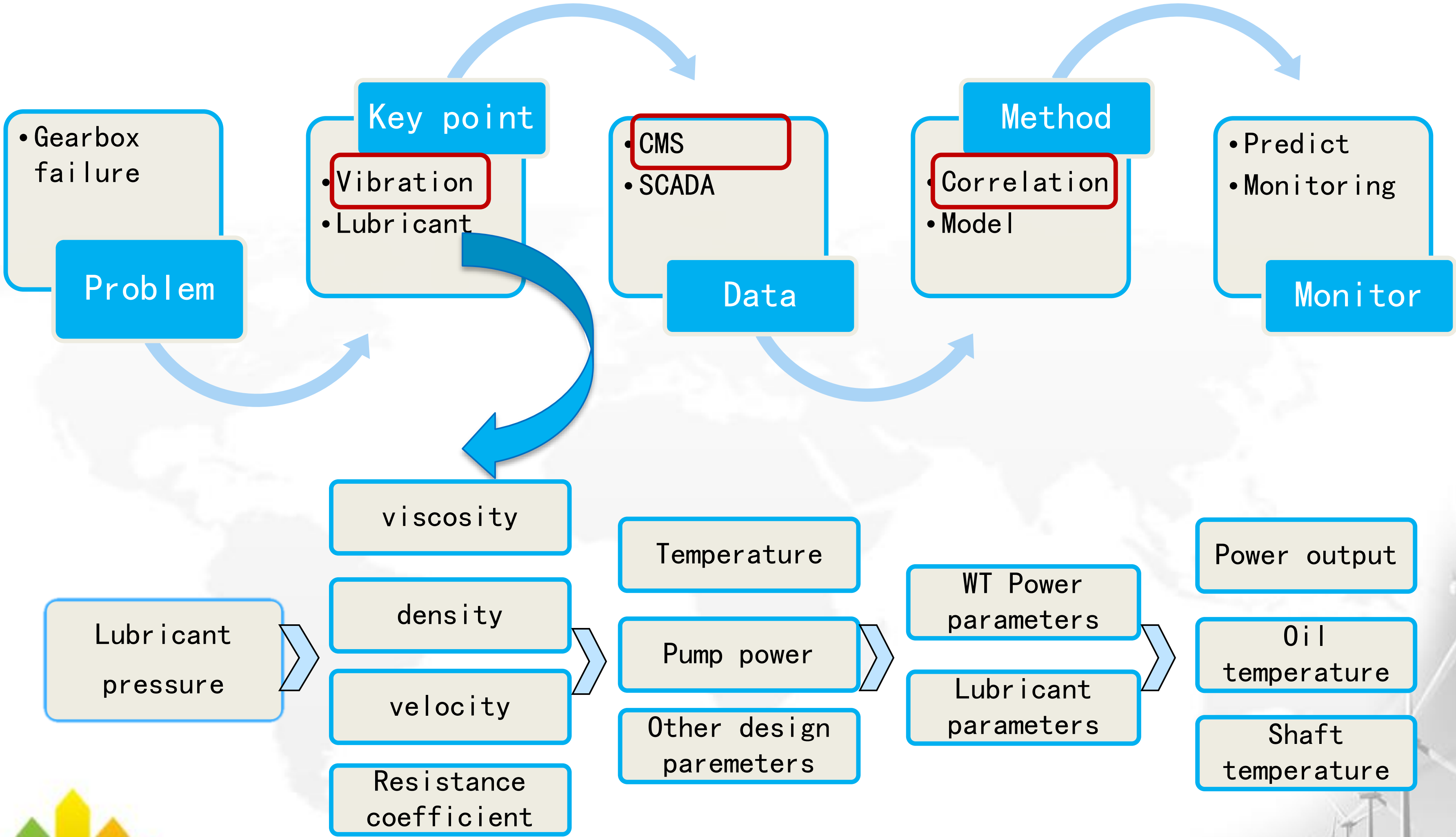
Vibration signals analysis



t pressure analysis



Root Cause analysis



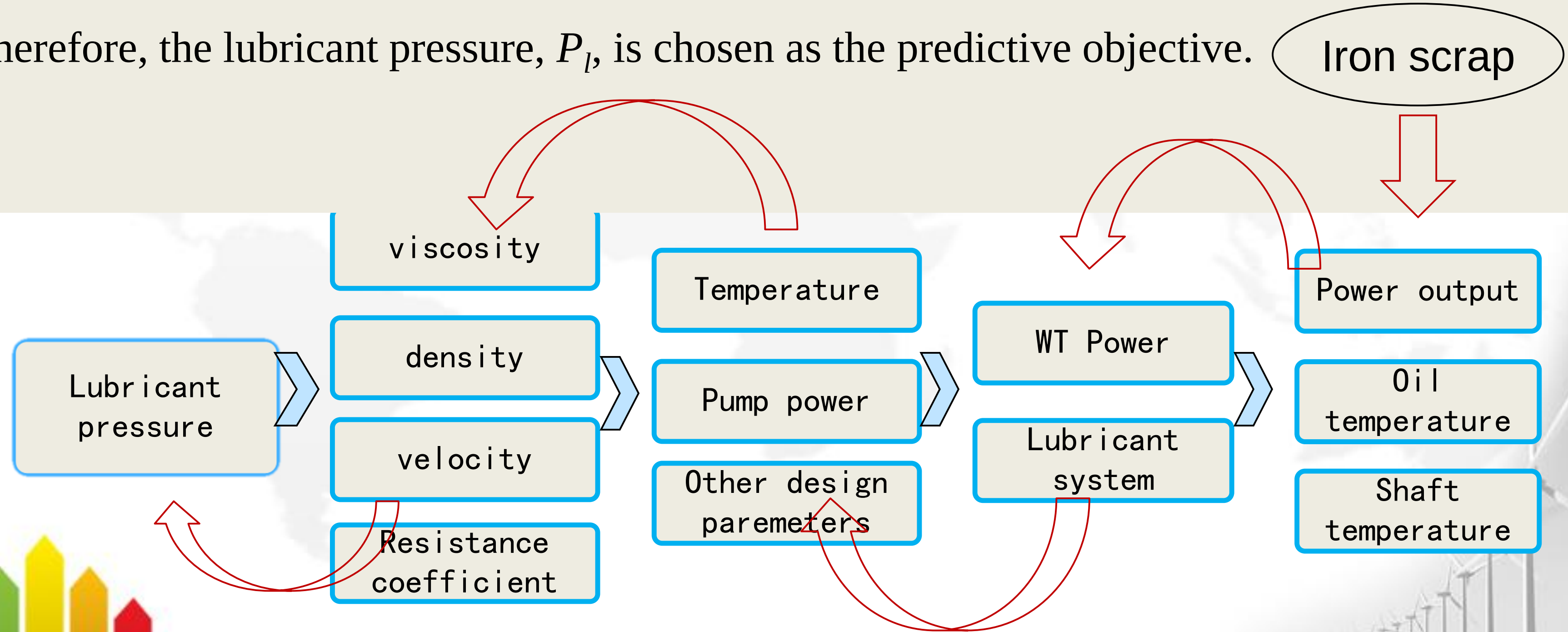
The effect of iron scrap

1、The lubricant is used to cool down the gearbox

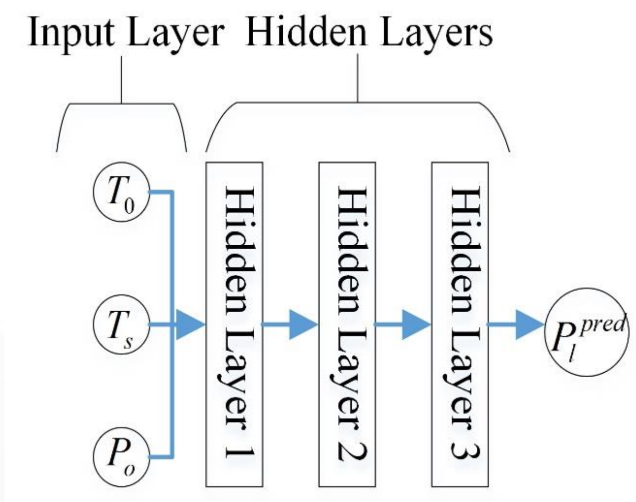
2、 The change of the lubricant pressure follows the change of the power output. Compared with the gearbox oil temperature, the lubricant pressure is more resistant to the impact of the environmental temperature.

3、 If there is the mechanical wear on the gearbox, the iron scrap will fall into the lubricant oil and the lubricant pressure will change.

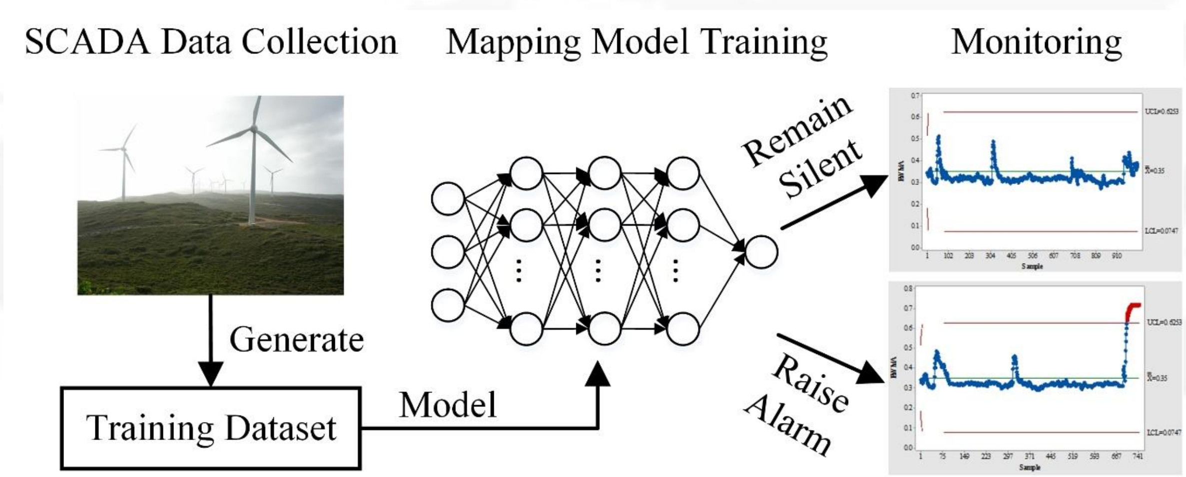
Therefore, the lubricant pressure, P_l, is chosen as the predictive objective.



The model for Gearbox – Deep Neutral Network



Gearbox oil temperature, T_o
Power output, P_o
Shaft temperature, T_s.



The schematic diagram of DNN

The model for Gearbox – Deep Neutral Network

Deep Neutral Network

The trained model is

$$\hat{P}_l = f(T_0, T_s, P_o)$$

The activation function:

$$\tanh(t) = \frac{e^t - e^{-t}}{e^t + e^{-t}}$$

The training process of DA is to learn the parameters,

$$\{\mathbf{W}_n, \mathbf{b}_n\} = \underset{\mathbf{W_n}, \mathbf{b_n}}{\operatorname{argmin}} \sum_{i=1}^{N} \frac{1}{2} (\hat{P}_l - P_l)^2, n = 0, 1, \cdots, L$$

EWMA Control Chart

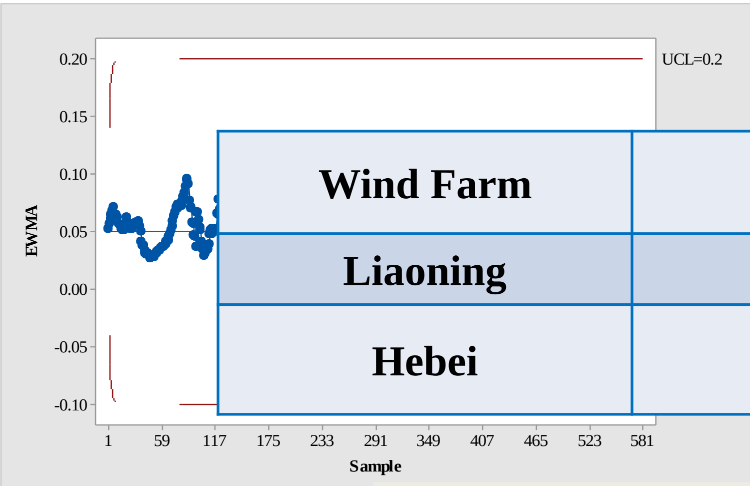
$$z_t = \lambda \mathrm{e}_{rt} + (1-\lambda) z_{t-1}$$

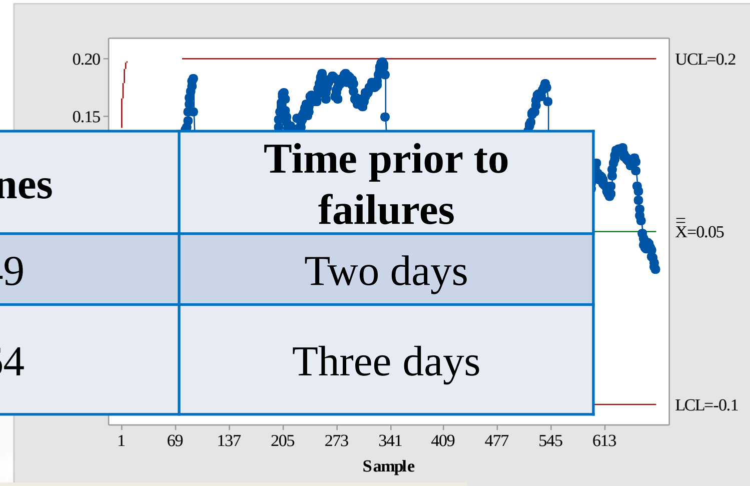
The upper and lower EWMA control limits depend on time

$$UCL(t) = \mu_{e_r} + L\sigma_{e_r} \sqrt{\frac{\lambda[1-(1-\lambda)^{2t}]}{(2-\lambda)n}}$$

$$LCL(t) = \mu_{e_r} - L\sigma_{e_r} \sqrt{\frac{\lambda[1-(1-\lambda)^{2t}]}{(2-\lambda)n}}$$

Cases - Gearbox



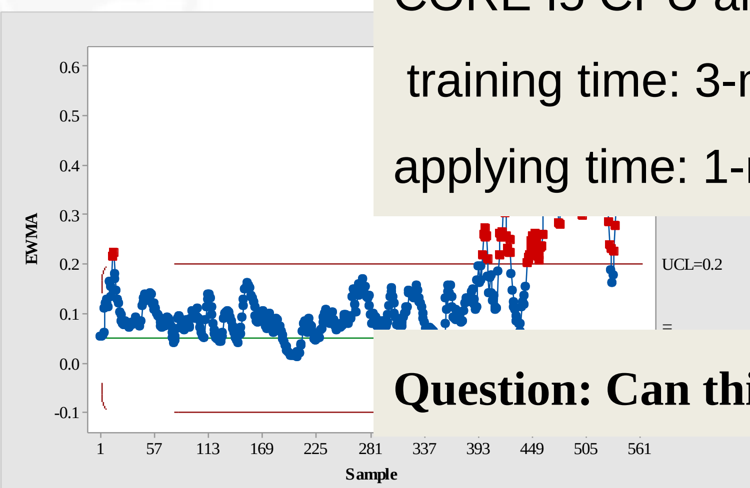


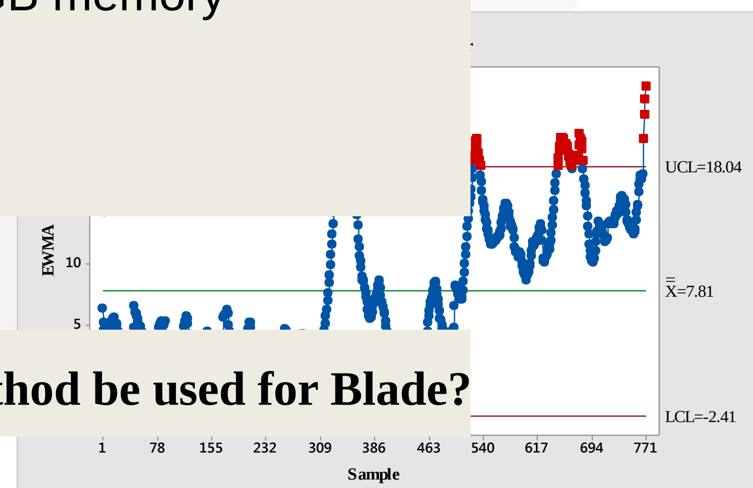
Wind Farm	Turbines	Time prior to failures
Liaoning	No 49	Two days
Hebei	No 64	Three days

CORE I5 CPU and 8GB memory

training time: 3-min,

applying time: 1-min.

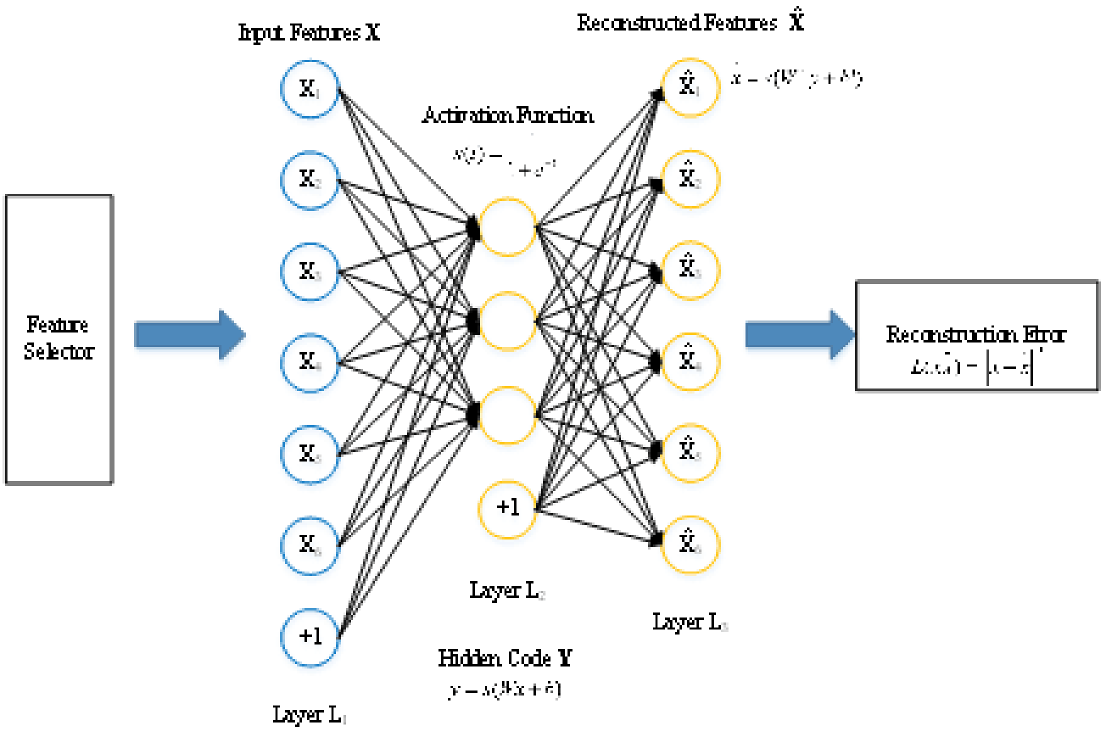




Question: Can this method be used for Blade?

The EWMA chart of normal and abnormal turbines

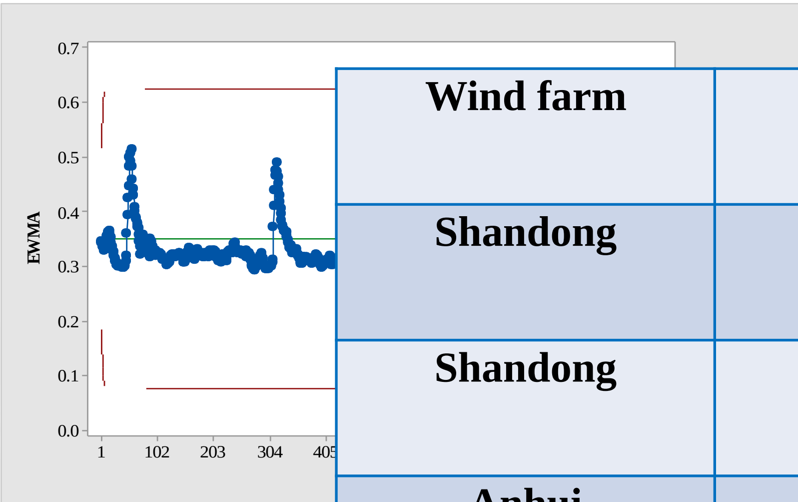
The model for Blade – deep autoencoder

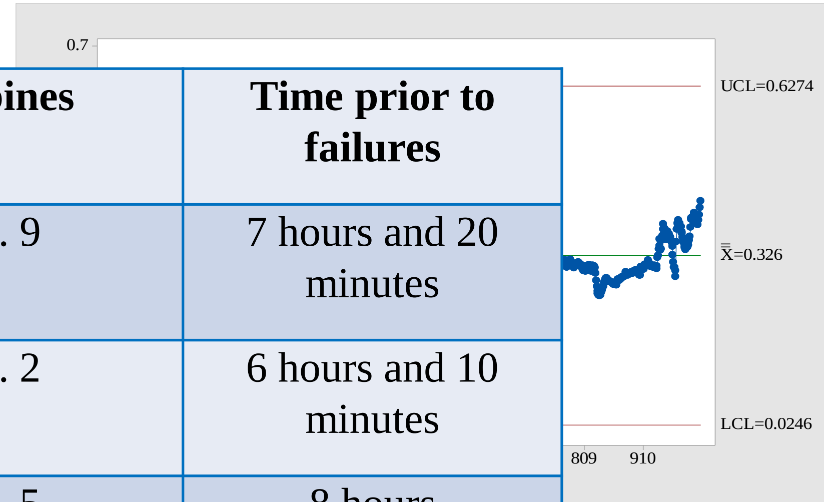


Schematic diagram of Deep Autoencoder

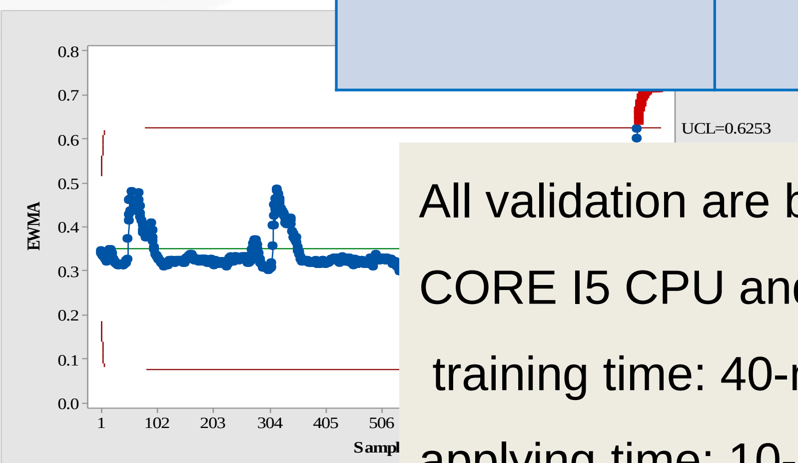
Parameter	Notation
wind speed	v_w
power	P
generator speed	v_g
rotor speed	v_r
U1 voltage	U_1
U2 voltage	U_2
U3 voltage	U_3
U1 current	I_1
U2 current	I_2
U3 current	I_3
power factor	f_p
power grid frequency	f_g
wind direction	D_w
wind angle	θ_w
blade angle	θ_b
environment temperature	T_e
nacelle temperature	T_n
gearbox oil temperature	T_g
hydraulic oil temperature	T_h
U1 winding temperature	T_{u1}
gearbox axis 1 temperature	T_{g1}
gearbox axis 2 temperature	T_{g2}
motor bearing A temperature	T_A
motor bearing B temperature	T_B
generating capacity	P_c

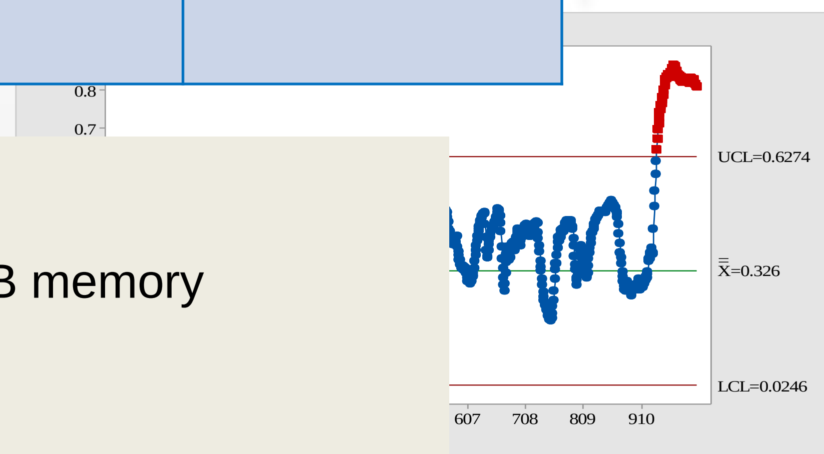
Cases - Blade





Wind farm	Turbines	Time prior to failures
Shandong	No. 9	7 hours and 20 minutes
Shandong	No. 2	6 hours and 10 minutes
Anhui	No. 5	8 hours





All validation are blind.

CORE I5 CPU and 8GB memory

training time: 40-min,

applying time: 10-min.

The EWMA chart of normal and abnormal turbines

Conclusions

- The DNN model is applicable to identify impending gearbox failure base on SCADA data.
- The DA model is applicable to identify impending blade failure based on SCADA data.
- The proposed method raised alarms early enough for the replacement or repair.
- There were no false alarms for failure monitoring.
- The effectiveness of these methods needs to be further examined by more cases.
- At present, these models have been deployed for monitoring the failure in a wind farm of Longyuan.

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