清華大學
Tsinghua University

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The Role of Data in Conventional Energy for a Green future

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Content

Introduction

Name card

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Tsinghua University

Research Interest:

- High efficient combustion and clean utilization of **fossil fuel**
- **High fidelity numerical modeling** of reactive multiphase flow
- **Intelligent** power generation of coal-fired power station
- Smart energy production with **low carbon**

Introduction

The Way We Describe the World

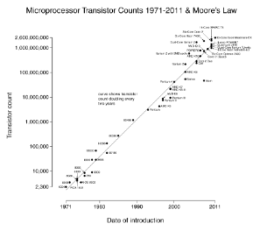
Fidelity

Cost

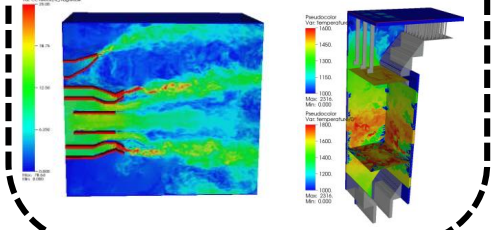
Laws

The first/second law of **thermodynamics**

Moore's Law

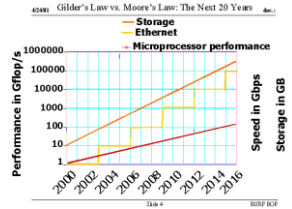


Modeling

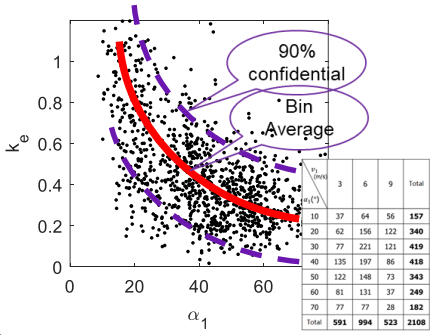


Data

.....



Gilder's Law



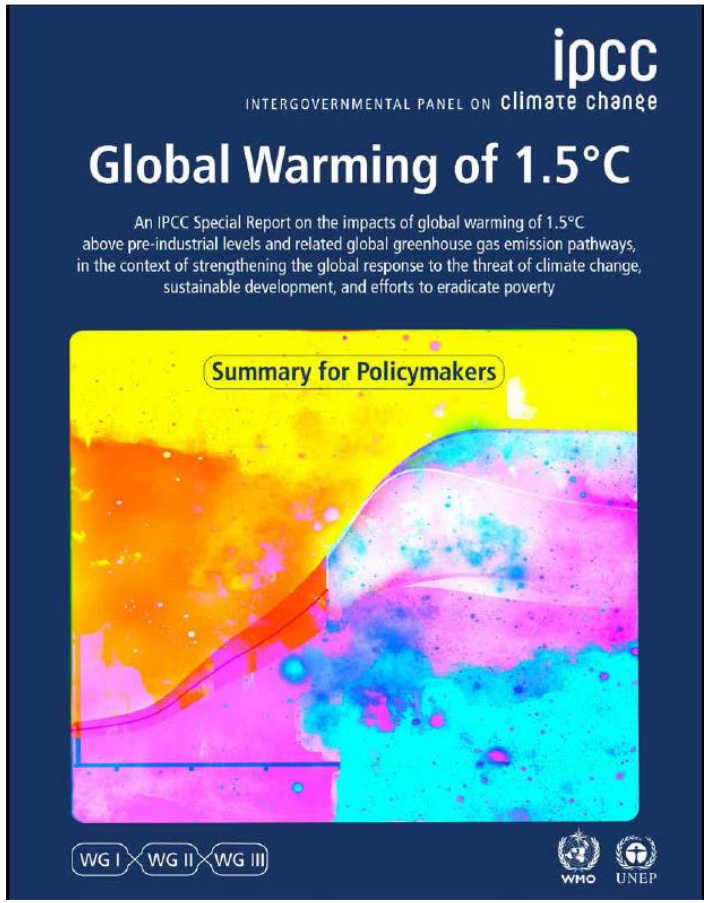
	3	6	9	Total
10	37	64	56	**157**
20	62	156	122	**340**
30	77	221	121	**419**
40	135	197	86	**418**
50	122	148	73	**343**
60	81	131	37	**249**
70	77	77	28	**182**
Total	**591**	**994**	**523**	**2108**

Especially in energy?

How we make the role of data in the future?

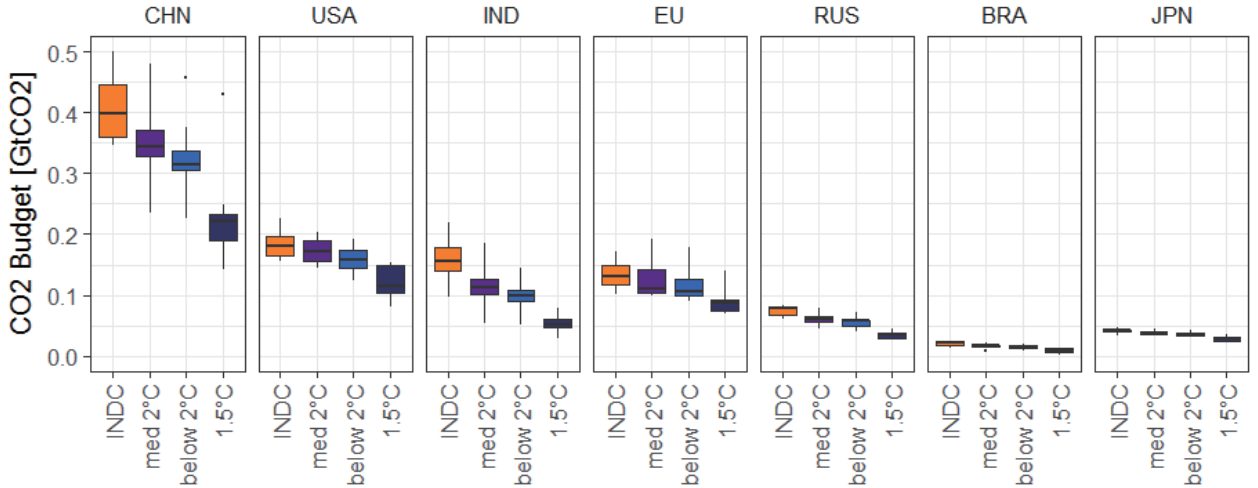
Introduction

Energy in future



1.5 ℃ : CO_2 emission declined by 45% in 2030 comparing 2010; **Zero** CO2 emission by 2050

2.0 ℃ : CO_2 emission declined by 25% in 2030 comparing 2010; **Zero** CO2 emission by 2070



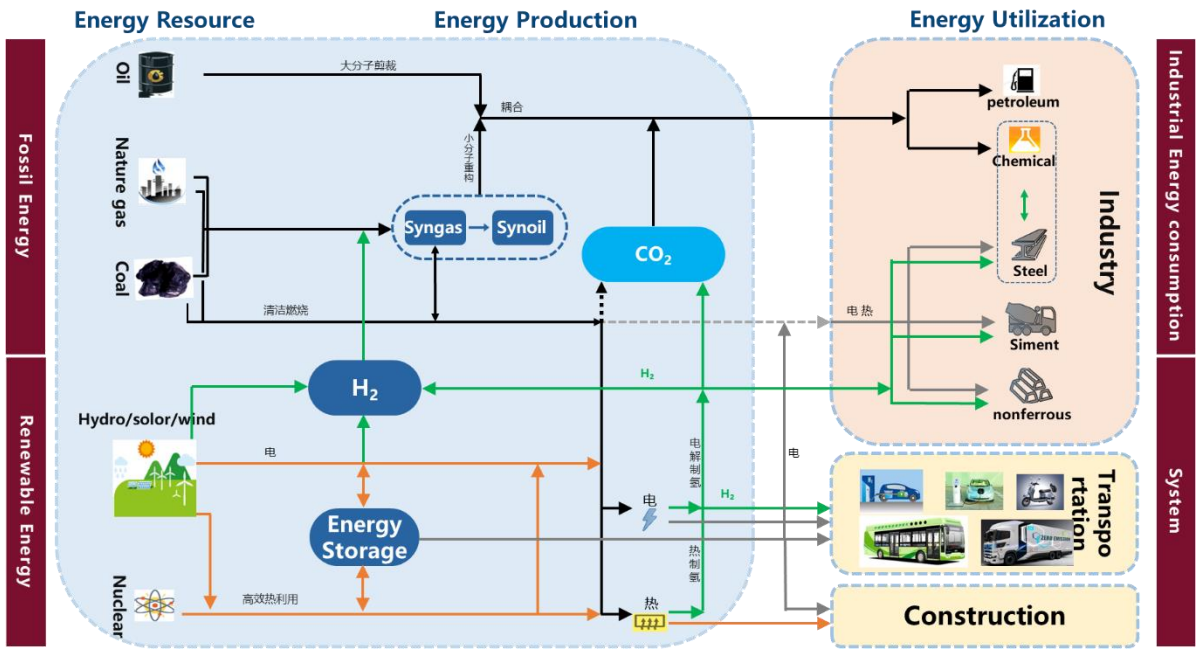
China's dual carbon goals:

- Bring carbon emissions to peak before **2030**
- Achieve carbon neutrality in **2060**

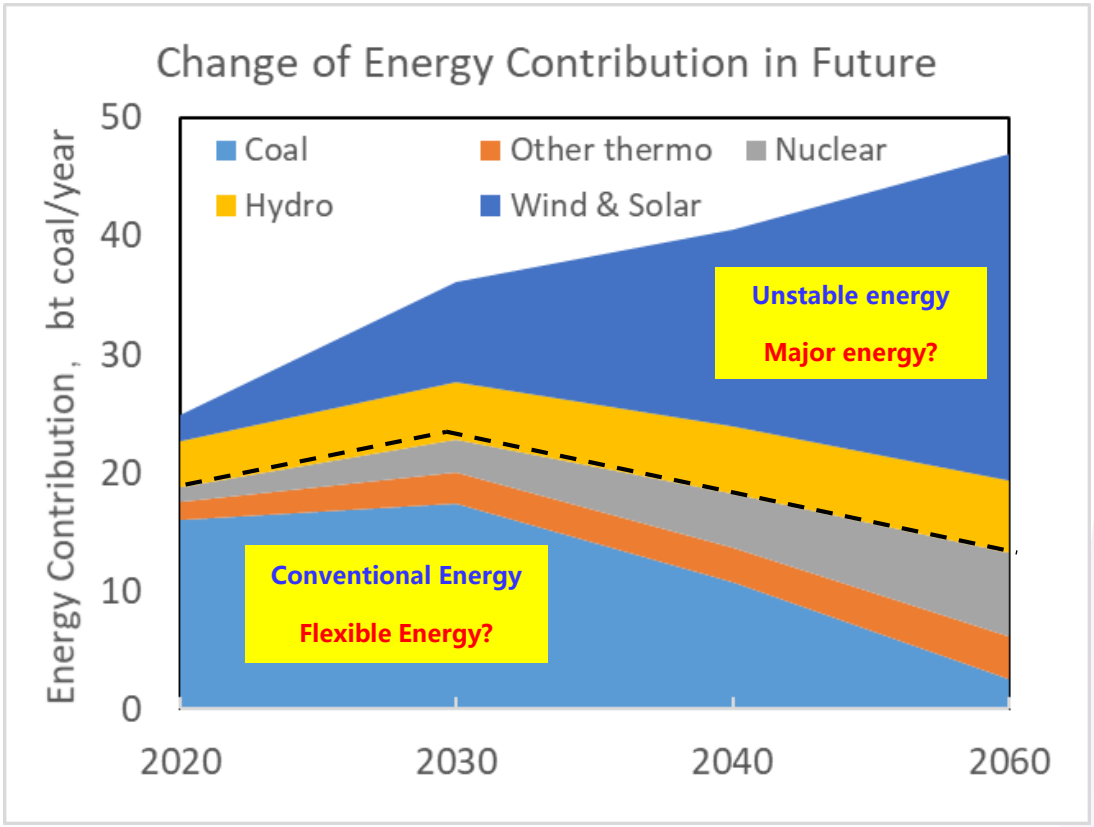
[1] China Coal consumption Cap Plan and Policy Research Project, 2018-05

Introduction

Energy in future



Multi-energy integration technology system of "four mainlines and four platforms"[1] from Chinese Academy of Science



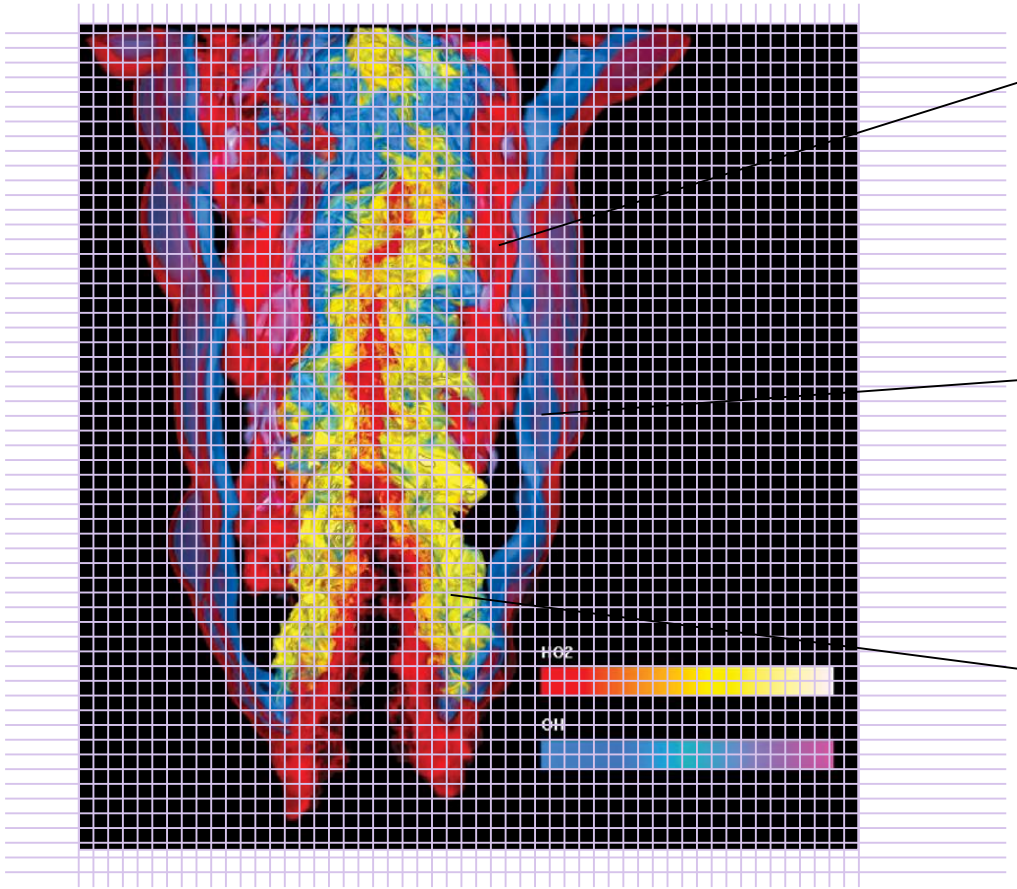
In ten years: How to improve the efficiency and flexibility of conventional energy?

Long term: How we find a way to combine the complex energy system?

[1] http://cn.chinagate.cn/news/2022-06/02/content_78250526.htm

Introduction

Numerical Modeling with high fidelity



Discretization of transport equations: Momentum, Energy, Species……

High fidelity need finer mesh size and shorter time steps, thus **sharp increase** of computation cost.

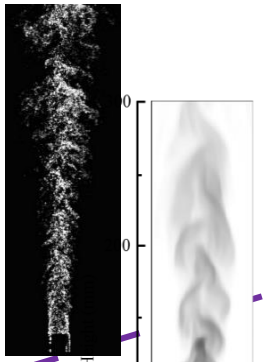
High fidelity means more information and **more data**.

Instantaneous radicals profile in a flame

Introduction

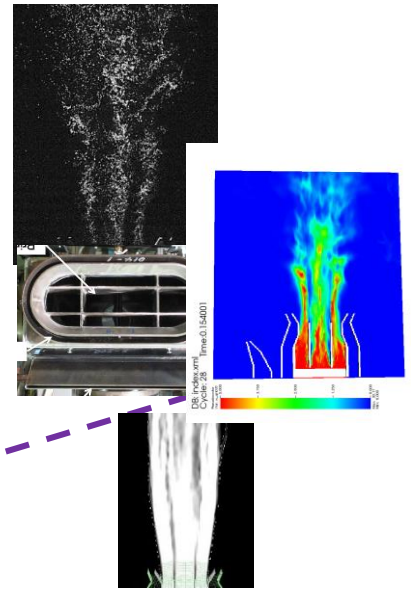
Numerical Modeling with high fidelity

round jet



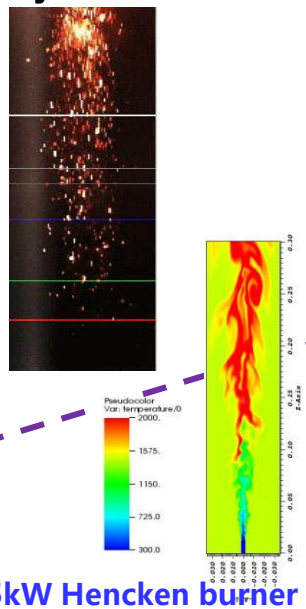
Particle laden jet

Coal burner



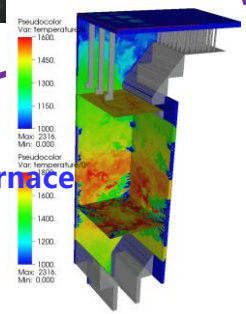
Flow field of coal burner

Coal jet flame



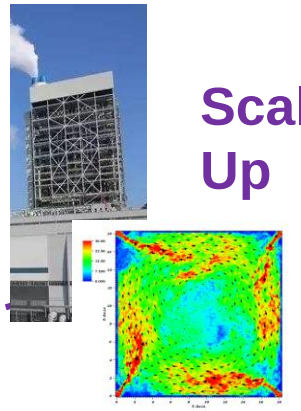
5kW Hencken burner

Coal fire boiler



13MW Oxycoal furnace

Scale Up



660MWSCC tower shape boiler

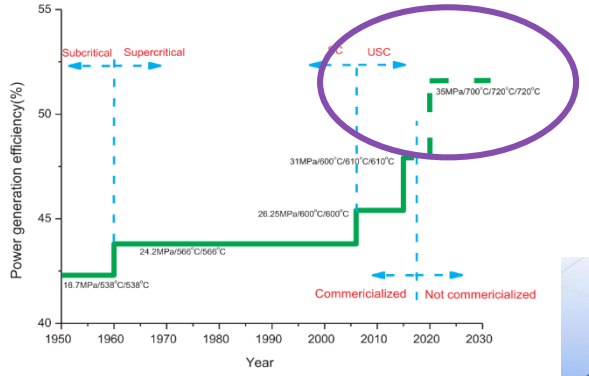
High fidelity model results in more data……

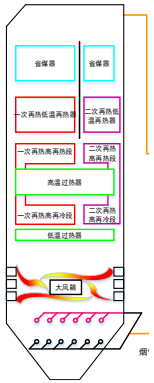
[1] Kailong Xu, Yuxin Wu, Haoshu Shen, et al. Fuel, 2017. 194: p. 297-305.
[2] Haoshu Shen, Yuxin Wu, Kailong Xu, et al. Fuel, 2018. 216: p. 475-483.

Content

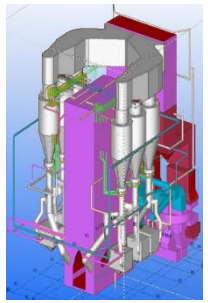
Data utilization in coal power plants

- The state-of-art of coal-fired power units in China[1]





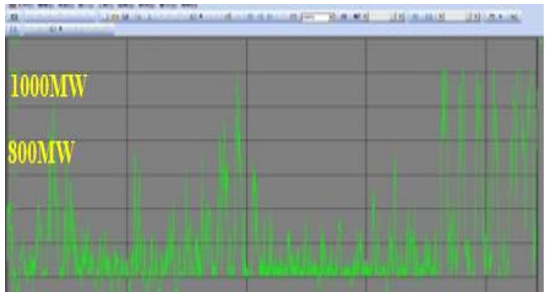
31MPa
600 /620/620 ℃



25.4/4.45MPa
571/569 ℃

660MW USCC-PC boiler in Suqian, 2019

600MW SCC-CFB boiler in BaiMa, 2013



Load change of a coal power plant

Operating hours of thermal power

High efficiency—— higher parameters with precise control

Complex goals——energy safety, low carbon and emission, high fuel cost……

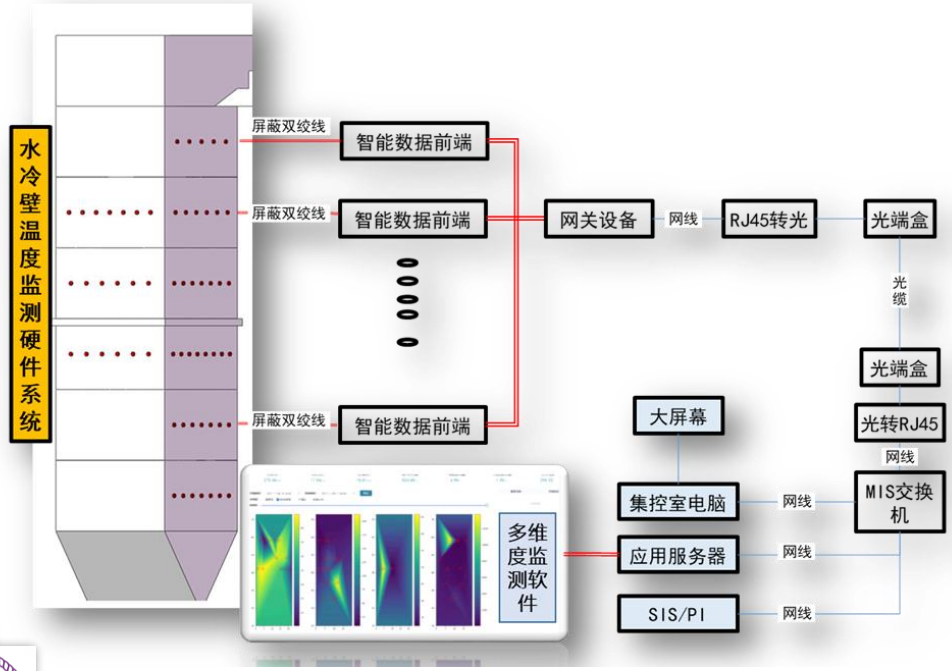
Flexibility —— To be fitful for the grid and future energy system

[1] Fan H, Zhang Z, Dong J, et al. Thermal Science and Engineering Progress, 2018,5:364-371.time

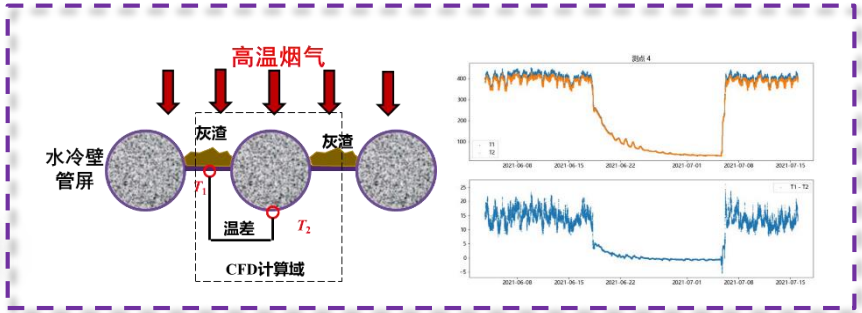
Data utilization in coal power plants

Monitoring heating surface safety online

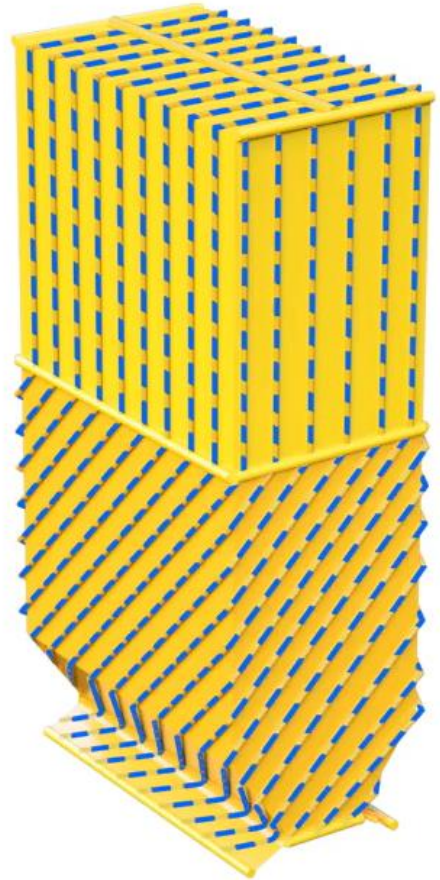
- Thousands of pipes running under high temperature (~650℃) and high pressure(~35 MPa).
- Pipe damage lead to abnormal shutdown.
- **Lacking the data to judge the crisis points.**



Data collection system



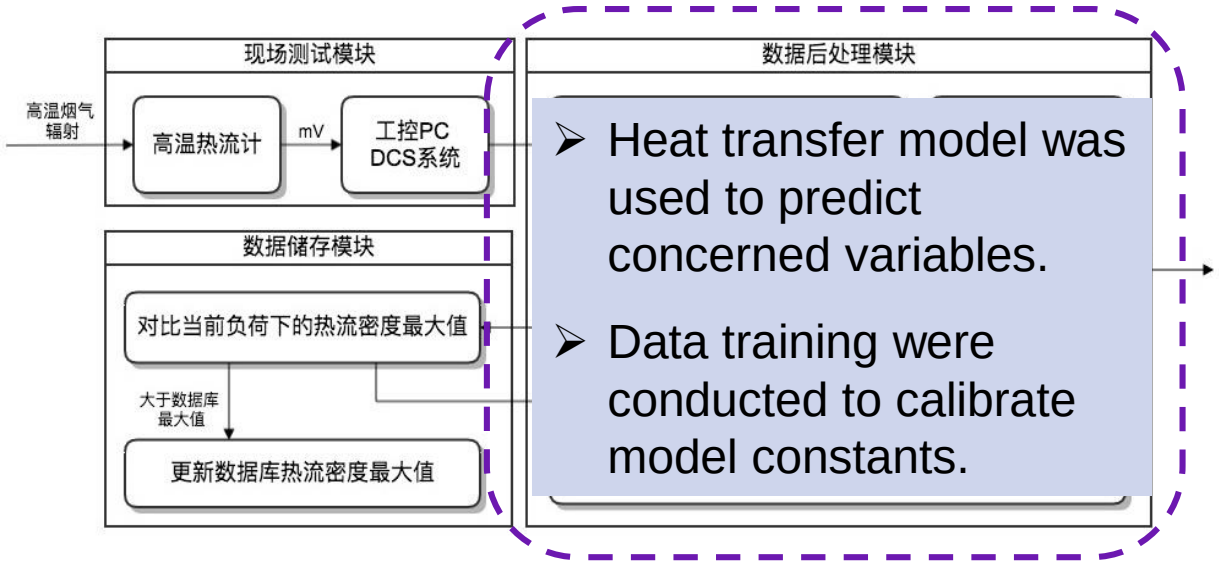
Challenge: how to identify the reason for uncertainties?
A model analysis based on historical data was developed.



Spirally wound water wall

Data utilization in coal power plants

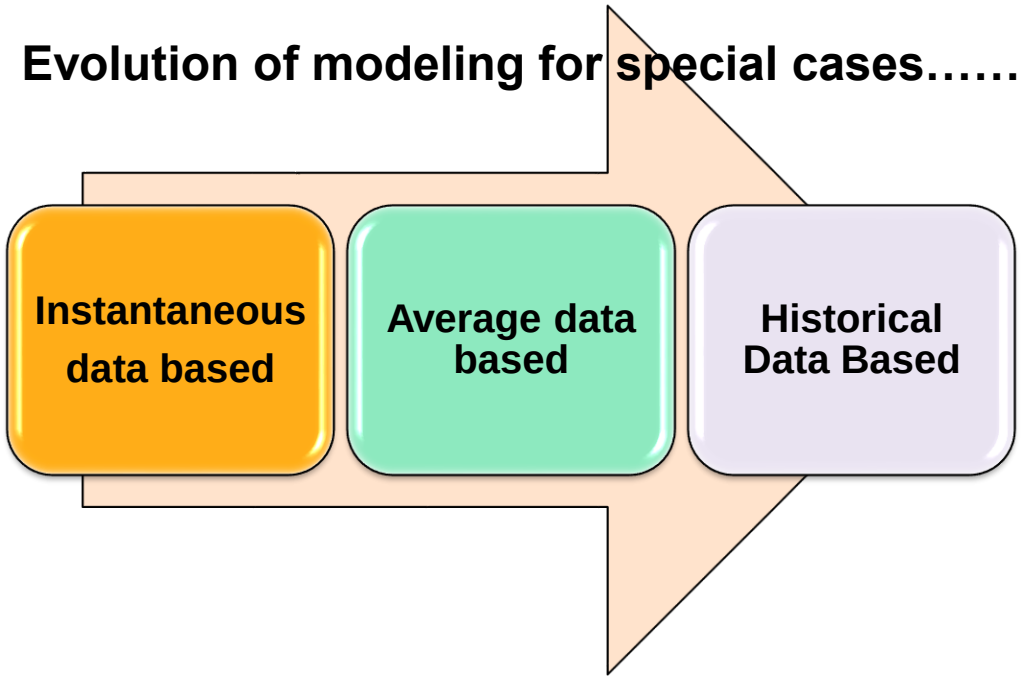
Monitoring heating surface safety online



- Heat transfer model was used to predict concerned variables.
- Data training were conducted to calibrate model constants.

A model analysis based on historical data was developed.

Evolution of modeling for special cases……

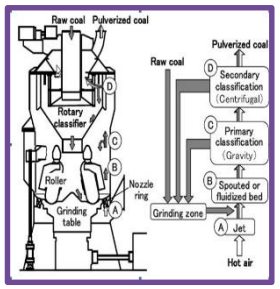


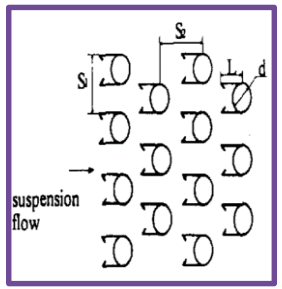
A bridge is desired between empirical models and data science.

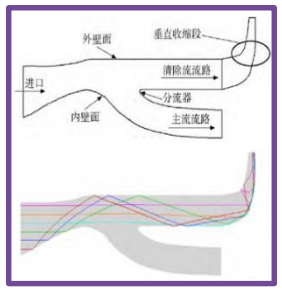
Data utilization in coal power plants

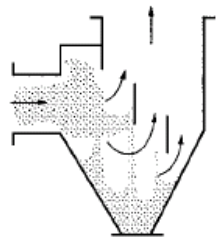
An example of scientific research

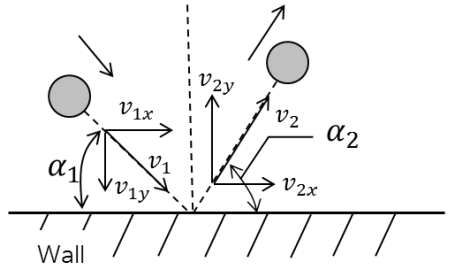
The key parameters: **Impact velocity, impact angle, particle diameter, wall roughness, particle material, particle sphericity**



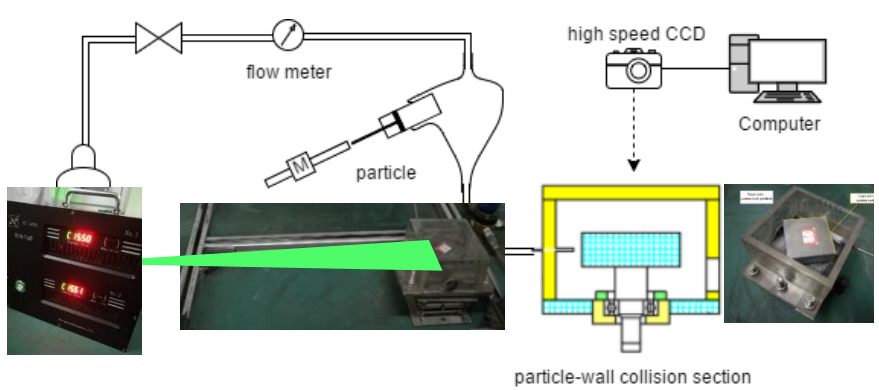




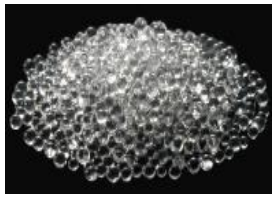




Particle impacting on wall is important for particle separation and dispersion.

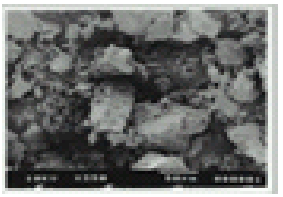


- 4200 fps
- ~100 μs
- 5 W laser slice



glass beads

glass powder



coal

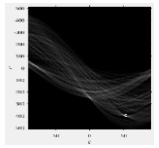
biomass

- Fundamental experimental investigations on particle-wall impactions were conducted
- A sliced laser was introduced to provide light source and reduce 3-d impact disturbance
- Different non-spherical particles were considered

Data utilization in coal power plants

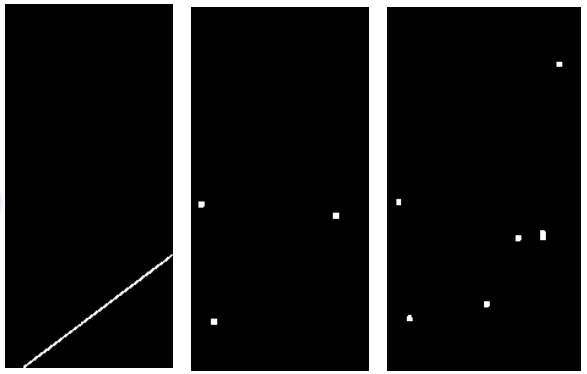
An example of scientific research

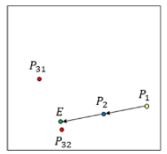
Image sequence



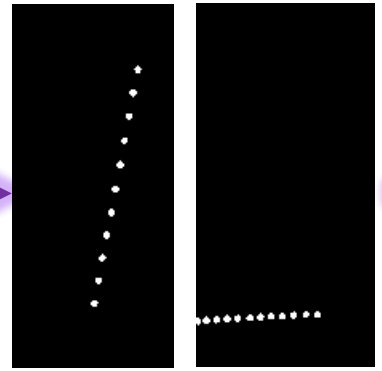
Hough transform for wall

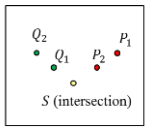
Wall and particle identification

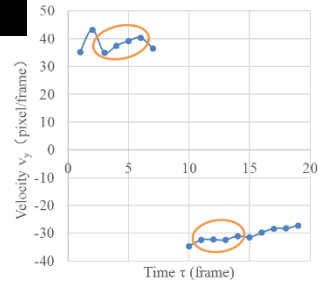




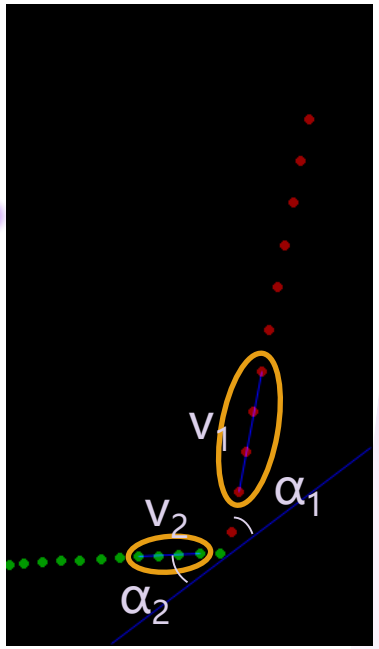
Particle trajectory

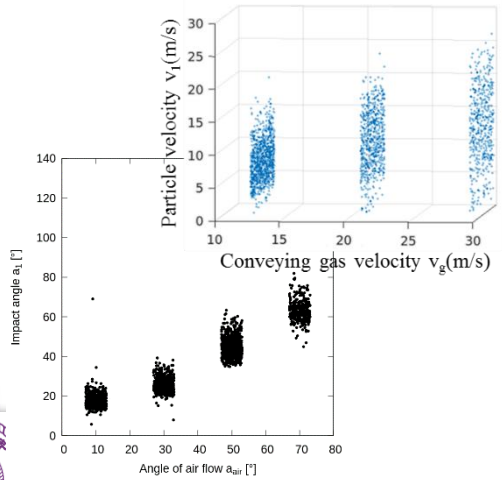






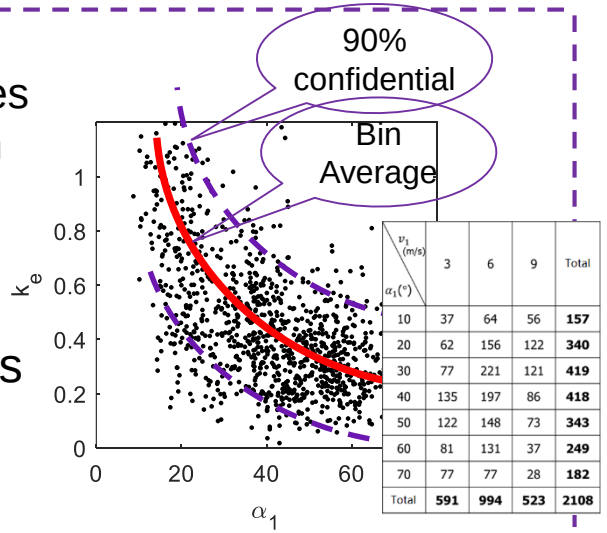
Final lines





Actual impacting velocities were determined through image identification

restitution coefficients Vs impacting angle



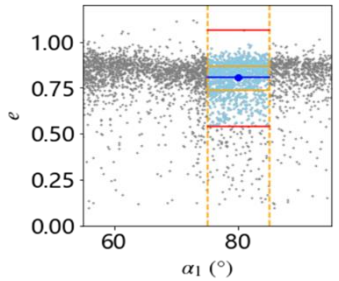
v_1 (m/s) \ α_1 (°)	3	6	9	Total
10	37	64	56	**157**
20	62	156	122	**340**
30	77	221	121	**419**
40	135	197	86	**418**
50	122	148	73	**343**
60	81	131	37	**249**
70	77	77	28	**182**
Total	**591**	**994**	**523**	**2108**

The average velocities were adopted to calculate the particle restitution coefficient and friction coefficient

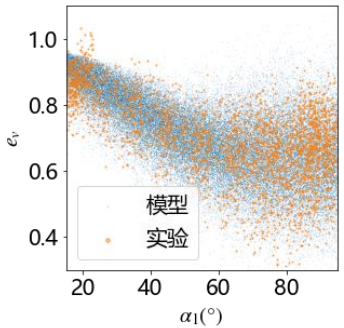
Data utilization in coal power plants

An example of scientific research

Modeling



Box plot: with 3% of data were removed, a decrease of 16% uncertainties was achieved.



A traditional model with four parameters $(e_m, \Delta e_m, f_m, \Delta\gamma)$ based on PDF function

$$\gamma = -\delta(\alpha_1 - \beta) \quad (\alpha_1 < \beta)$$
$$\gamma = 0 \quad (\alpha_1 > \beta) \qquad \gamma \sim N(0, \Delta\gamma^2)$$
$$\delta = \left(\frac{e_{v,modal}}{e_{v,data}} - 1\right)^2 + \left(\alpha_{2,modal} - \alpha_{2,data}\right)^2$$

Neural network

Input layer	
Input	Output
(?, 5)	(?, 5)

→

Full Connection	
Input	Output
(?, 5)	(?, n)

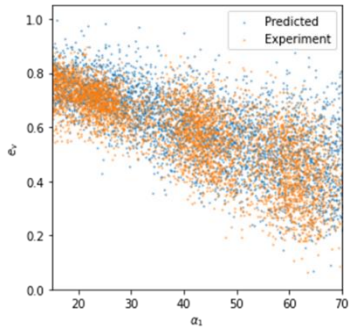
→

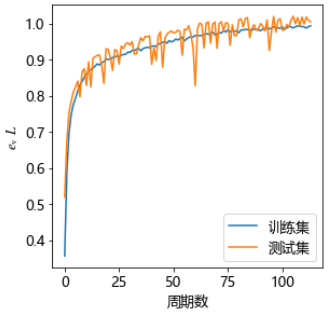
Full Connection	
Input	Output
(?, n)	(?, 2)

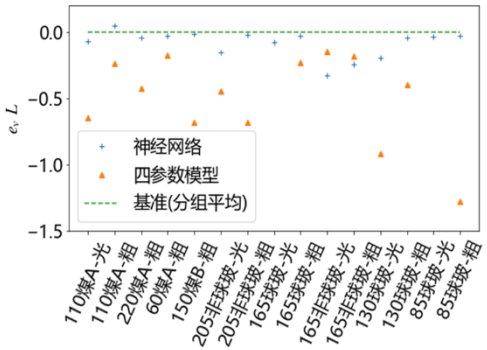
→

Full Connection	
Input	Output
(?, 2)	μ, σ

$N(\mu, \sigma)$







Properties → Hidden layer → Property neural

The second Layer

InputLayer	
input:	output:
[(None, 4)]	[(None, 4)]

→

Dense	
input:	output:
(None, 4)	(None, 7)

→

Dense	
input:	output:
(None, 7)	(None, 1)

The first Layer

InputLayer	
input:	output:
[(None, 2)]	[(None, 2)]

Collision parameters

Connection layer → Hidden layer(30) → Output

Concatenate	
input:	output:
[(None, 2), (None, 1)]	(None, 3)

→

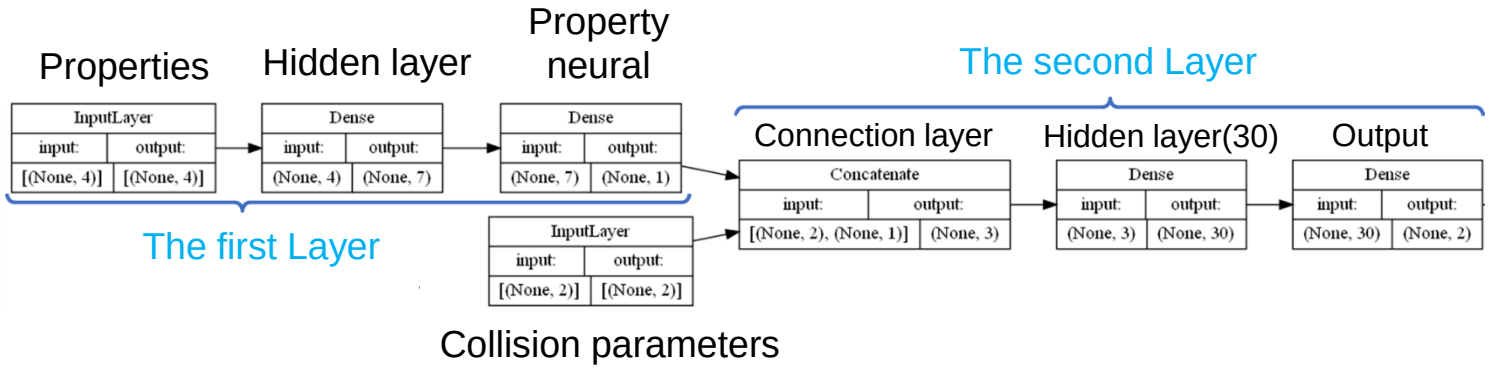
Dense	
input:	output:
(None, 3)	(None, 30)

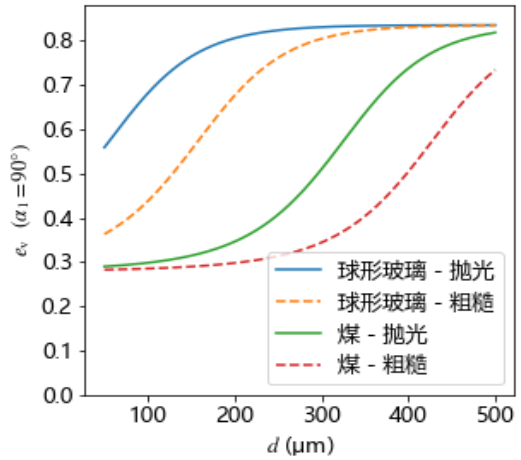
→

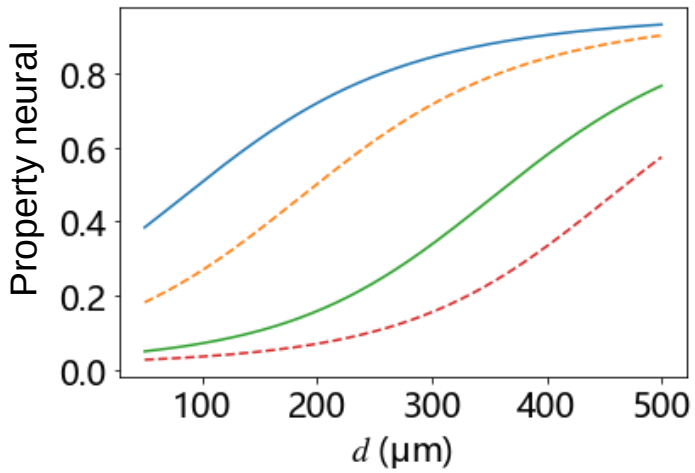
Dense	
input:	output:
(None, 30)	(None, 2)

Data utilization in coal power plants

An example of scientific research

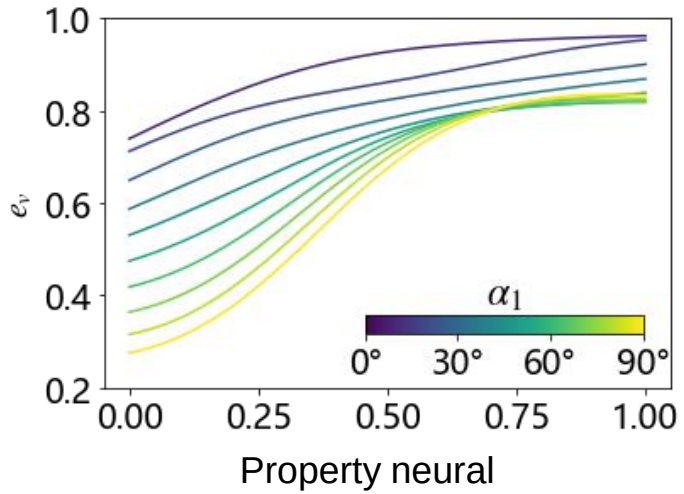






A two layer neural network is used to help understand physics.

The property neural output helps identify the dominant parameters(particle size).

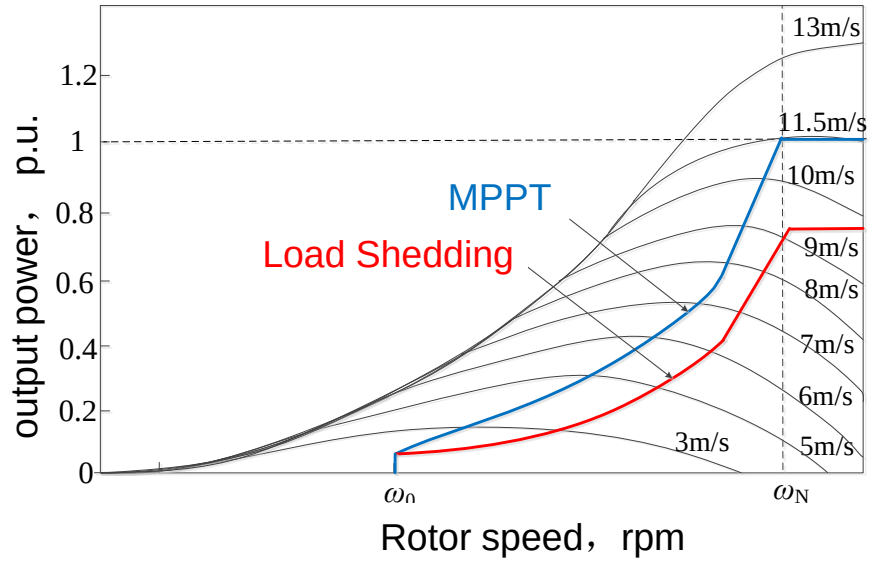


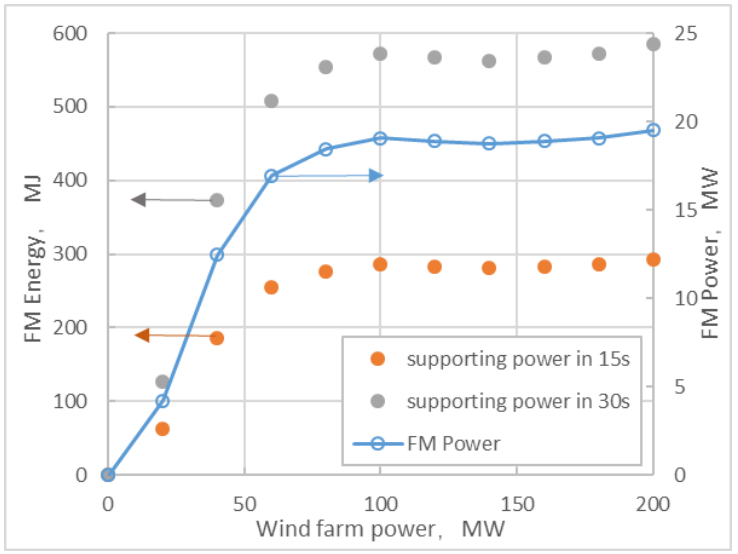
Content

Wind energy for flexible grid

Conventional coal firing power plants: fitful for peak regulation, the response time is larger than 30 s. The conventional energy is hard to provide abilities of frequency regulation in short time.

Is it possible for wind energy to contribute to frequency regulation?



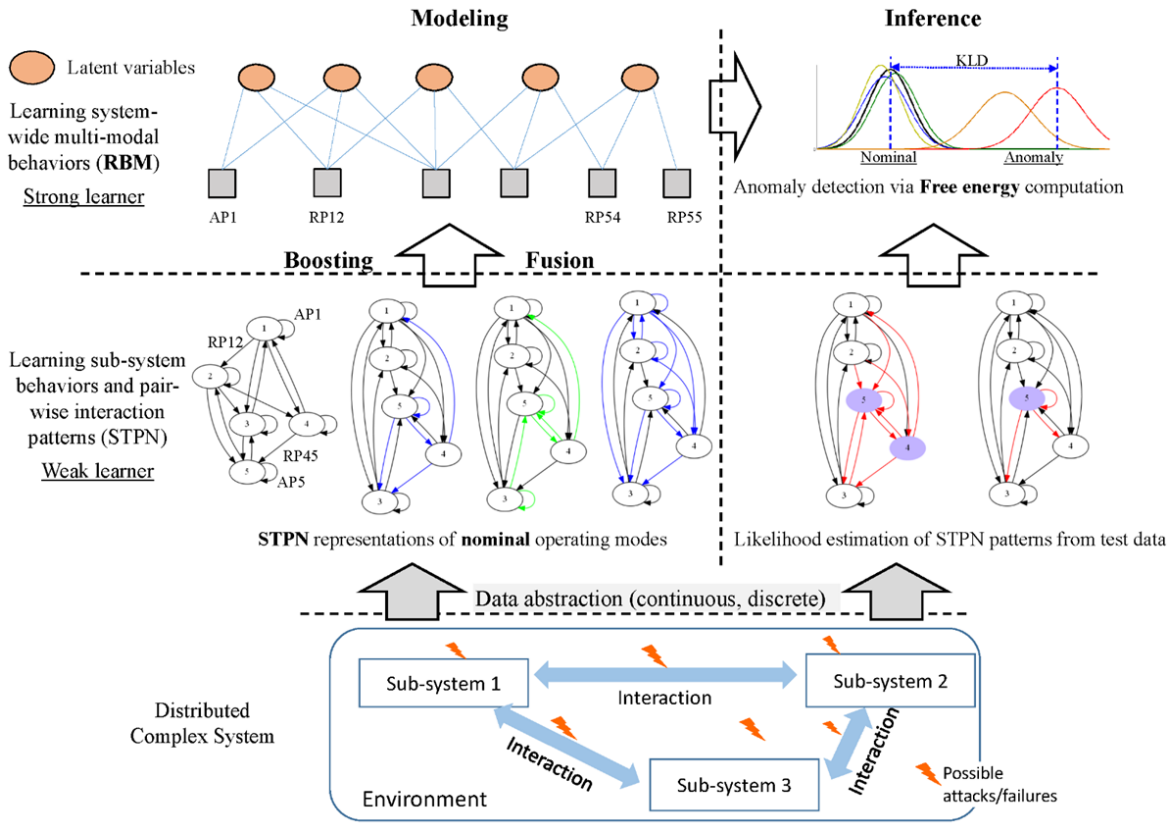


The theoretical analysis based on a wind farm's operating data show there is a great potential for a wind farm to reserve power to fulfill the energy required for frequency regulation.

[1] TANG Jian, TANG Qing-hong, YAO Yu-ge, SU Jian-tao, et al. Analysis of the potential frequency regulation ability of wind power based in the view of energy

Wind energy for flexible grid

Research of AI in wind energy at Tsinghua University



Anomaly detection for renewable energy systems

Jiang Dongxiang
Professor

Liu Chao
Asso. Professor

a) Learning of APs & RPs, computing causality with *inference based metric*, and normalization

b) *Boosting* of multiple STPNs, i.e., *fusion* of multiple nominal modes

c) *Unsupervised learning* of system-wide characteristics

d) *Anomaly detection* via computing probability of occurrence of the current state.

[1] Liu, C., Jiang, D., & Yang, W. (2014). Global geometric similarity scheme for feature selection in fault diagnosis. Expert Systems with Applications, 41(8), 3585-3595.

Wind energy for flexible grid

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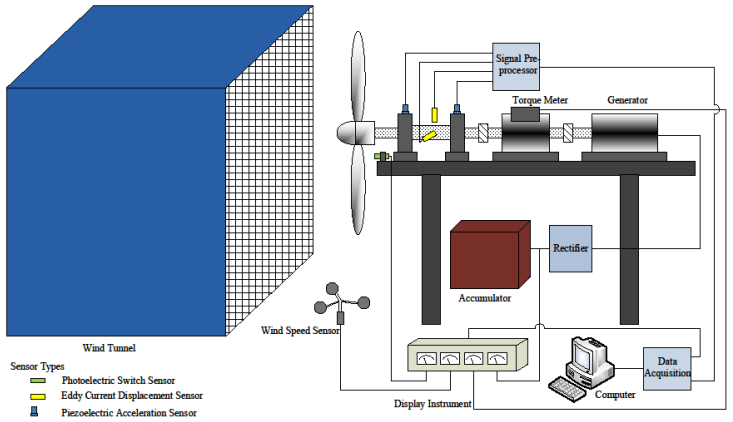
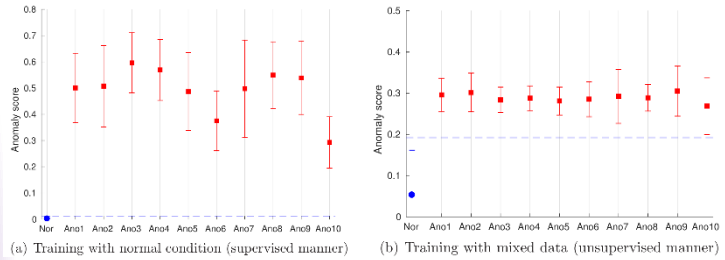
Experimental study

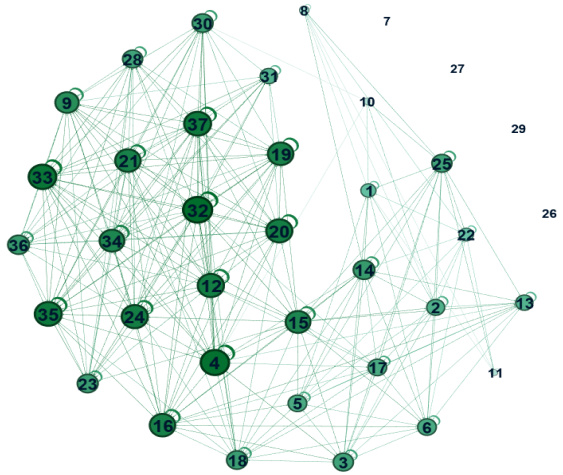


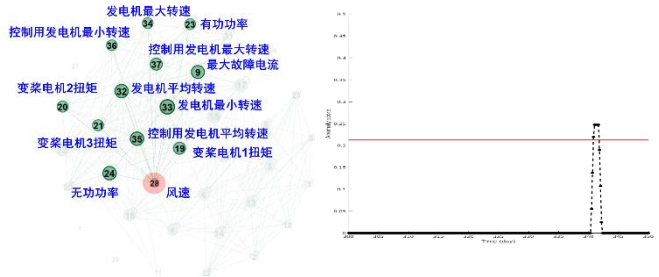


(a) Training with normal condition (supervised manner)

(b) Training with mixed data (unsupervised manner)

Field Data





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Both experimental data and field data were used to test the anomaly detection frame work.

The supervised manner and unsupervised manner works well for anomaly detection.

Causal discover visualization could be achieved through the model on SCADA data.

[1] Liu, C., Jiang, D., & Yang, W. (2014). Global geometric similarity scheme for feature selection in fault diagnosis. Expert Systems with Applications, 41(8), 3585-3595.

Wind energy for flexible grid

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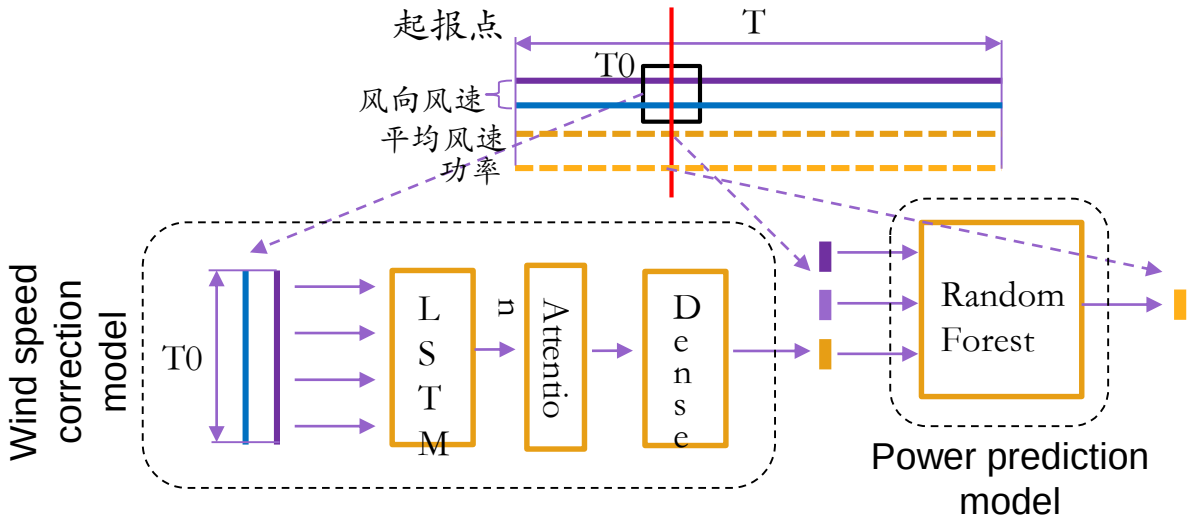

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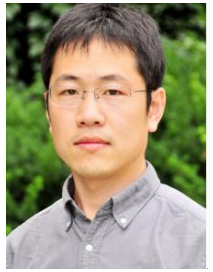

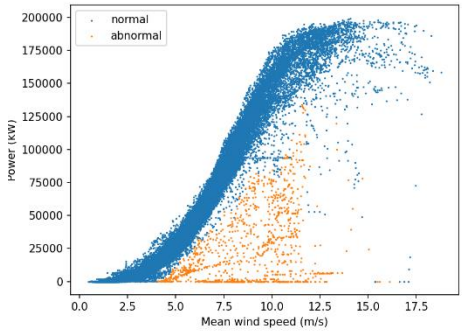

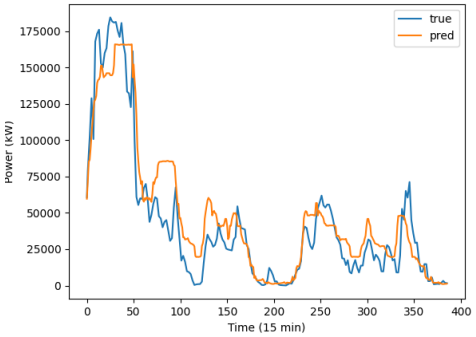

The model combined wind speed correction and weather forecast

Data washing

Prediction

A wind power forecasting model was proposed considering the weather forecast and wind speed correlation model.

Data washing and wind speed correction can both improve the prediction results.

[1] Liu, C., Jiang, D., & Yang, W. (2014). Global geometric similarity scheme for feature selection in fault diagnosis. Expert Systems with Applications, 41(8), 3585-3595.

Content

Conclusions

- Data driven based methods will play more and more important roles in the complex energy systems.
- A bridge is need for traditional modeling and data science for higher efficiency and stronger performance. Historical data is also considering in the traditional modeling work.
- it’s important to get the essential data for good prediction either in a coal power plant or a wind farm. The combination of conventional energy and wind farms can help construction of a flexible grid.
- Some progress of AI research on wind energy at Tsinghua has been reported.

Thanks for your attention !