Artificial Intelligence Apps in IIOT

By Zhu Weilie, CIO of China Huaneng Group Co.
Education Background

- BA in Gas Turbine, School of Thermal Engineering at Tsinghua University
- MS in Thermal Turbines, School of Thermal Engineering at Tsinghua University
- MBA, Business School of Tsinghua University

Self-introduction

Working Experience

- Chief Information Officer of the China Huaneng Group co.
- Receiver the state council special allowance.
- Contributing Vice Chairman of China Information Industry Association
- Executive director of China Computer Society
- Chairman of IIOT and Big Data Application Association

China Huaneng (CHG):
- 13-year experience in electricity production, construction, planning and operation management.
- 15-year experience in IT management

Chinese Academy of Sciences
- 3-year experience in technology research
CONTENTS

1. Practice of A.I. in industry
2. Perspectives of A.I.
3. All in A.I.
Development of CHG IIOT program

2012
Early exploration in Big Data Application

2013
Data Integration and collection standards

2015
Data computation standard

2017
Application test
Organize industry alliance

2018年
Smart industry + Eco system construction

Development of CHG IIOT program
reliability
(anomaly detection, root cause)

Economic operation
(optimization)

Challenge from factory
(base on demand)

We solve all problems which above by using A.I.
(1) Traditional VS A.I.—Reliability, Usability

Condition-based maintenance is always our goal. We make it true!
Hydropower unit lower frame vibration ramp rate
The runner reel failure analysis

Hydropower unit health index evaluation system launched

- The features of top cover horizontal vibration and centrifugal force ramped up since Jun 6 2017, at the end of Sep the ramp rates were continuously rising.
- System sent out anomaly signal and failure warning
(2) Traditional VS A.I.—Economic Operation

- **Experiment**
  - Unit load
  - Coal type
  - ... (input)

- **Traditional**
  - Blending burning
  - Economic operation

- **A.I.**
  - Power rate efficiency
  - Coal type
  - ... (input)
  - Neural network
  - Economic operation (output)
Case — Using A.I. to guiding blending burning

- 算子功能模块
- 原始量
- 计算值
- KAM展示

- 火焰中心调节引导
- 燃煤挥发分掺配引导
- 燃煤热值掺配引导
- 总风量调节引导
- 炉膛压力调节引导
- 高加水位调节引导
- 低加水位调节引导
- 除氧器水位调节引导
- 循环冷却水调节引导

- 最优发电技术煤耗
- 最优发电热效率

- 水冷壁煤耗
- 过热器煤耗
- 压力热耗
- 烟气热耗
- 凝汽器煤耗

- 稳态工况参数
- KAM展示

- 多元线性回归
- 一元线性回归

- 数据库

- 图例

- KAM展示 (最优效率、煤耗)
- KAM展示 (运行引导)
Input parameters
- 发电技术煤耗
- 发电热效率
- 锅炉效率
- 汽机效率
- 煤热系数
- 省煤器煤耗
- 过热器煤耗
- 凝汽器煤耗
- 总风量
- 炉膛压力
- 高加水位
- 除氧器水位
- …

Multivariate regression model
- $y = k_1x_1 + k_2x_2 + \ldots + k_{18}x_{18} + \varepsilon$

Tuning parameters
- 模型参数解析
- 形成引导项

Guide chart

<table>
<thead>
<tr>
<th>调整参数</th>
<th>引导方式</th>
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<tbody>
<tr>
<td>火焰中心（左右）</td>
<td>给出火焰水平位置调整方向</td>
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<tr>
<td>火焰中心（上下）</td>
<td>给出火焰高度调整方向及对整体煤耗的调节影响量</td>
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<tr>
<td>煤热系数</td>
<td>给出煤种整体挥发分含量的调整方向及对整体煤耗的调节影响量</td>
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<td>热系数</td>
<td>给出煤种整体热值的调整方向及对整体煤耗的调节影响量</td>
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<tr>
<td>总风量</td>
<td>给出炉膛总风量的调整方向及对整体煤耗的调节影响量</td>
</tr>
<tr>
<td>炉膛压力</td>
<td>给出炉膛压力的调整方向及对整体煤耗的调节影响量</td>
</tr>
<tr>
<td>高加水位</td>
<td>给出高加水位的调整方向及对整体煤耗的调节影响量</td>
</tr>
<tr>
<td>除氧器水位</td>
<td>给出除氧器水位的调整方向及对整体煤耗的调节影响量</td>
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<td>低加水位</td>
<td>给出低加水位的调整方向及对整体煤耗的调节影响量</td>
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<tr>
<td>凝汽器循环冷却</td>
<td>给出循环冷却水的调整方向及对整体煤耗的调节影响量</td>
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调整参数的数学模型：
$$y = k_1x_1 + k_2x_2 + \ldots + k_{18}x_{18} + \varepsilon$$
Optimal operation system interface

- Coal consumption optimization
- Operation monitoring
- Flame center monitoring
- Operation guiding
Case-detection of High temperature pressurizer leak

Only notice when leaking above certain level

Model design: water level, water temperature, valve opening level

We can detect the deflect much early

Data points outside time range

5号机组

6号机组

#5机 1号高加未泄漏  #5机 2号高加未泄漏  #5机 3号高加未泄漏  #6机 1号高加未泄漏  #6机 2号高加未泄漏  #6机 3号高加未泄漏
If the coal mill output decreases, the coal fineness decreases, the unit load is too low for running.

Model design:
Coal mill power rate, Coal mill output

Optimizing:
Find the optimize point between coal mill output rate and steel ball adding rate

Make sure the unit load is above the minimum rate and the cost of adding steel ball is minimum.
The new developed wind power Apps
1. Practice of A.I. in industry
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(1) The characteristic value of industry

We have leading technology from the characteristic value of language and picture to the characteristic value of industry.

From measured value to the characteristic value

from phenomenon to essence

$F = Ma$

$R = U/I$

Vehicle fuel consumption

A.I. is not only can be us in identifying of voice and picture.
(2) AI used for maintenance shall solve personalization problems

Detection of malfunction is personalized.

The detection rate of malfunctions shall be over 95%.

The value of statistic can only solve the problems regarding re-designing and re-manufacture.

We can diagnose malfunction on a personalized basis.

The traditional method and algorithm stays in the level of common questions, which can not detect malfunctions in reality.

The ex-chief scientist of Baidu, Andrew NG, used machine learning to solve the problem regarding the maintenance of equipment, but his method can’t solve the personalization problem.
(3) different level of A.I. Apps

- Outsource data
- Location
- Digital twin
- Smart transportation
- Weather
- Digital twin
- Equipment data
- Car assemble
- Digital twin
- Car body
- Digital twin
- Brake
- Digital twin
- Engine
- Digital twin
- Transmission
- Digital twin
The high level A.I. app gain huge benefit

The cost of surplus water in Sichuan Province

2014
9.68 (billion KWH)
~3 (billion RMB)

2020
35 (billion KWH)
~10 (billion RMB)

Carbon emission
Meteorological information
electrovalence
Control information

注: 数据来源国家能源局《水电基地弃水问题驻点四川监管告》
Intelligence: the understanding to neural breaks up into 3 processes

1. Perception: picture, voice, sense, collect
   - Dragonfly, snake
   - Perception: collect information: picture, temperature, odour

2. Understanding: calculate, modeling, compare, judge
   - Perception: collect date through sensor, edge computing
   - Understanding of AI: data modelling

3. Output: action, execute
   - Dangerous? Run away? Food? Eat?
   - Prediction
   - Decision-making optimization

We break up the above process into 3 products
Productization

KDM
KKS Dynamic Data Management

Perception

- KKS management and service of KKS coding
- KDM data platform

- Full KKS data coding system
- Rich industrial communication protocols and database interfaces
- Embeddable enhanced time series database
- Data preprocessing and edge computing
- WebService data service interface

Understanding

- Algorithm configuration and management
- Stream algorithm module 1
- Stream algorithm module 2
- Stream algorithm module 3
- ... stream algorithm module n
- Data output interface
- KDM data platform

- Model building and application development and running platform
- Stream computing engine, online real-time running
- Multiple statistical learning algorithms and computing modules
- Computing flow configuration and running environment
- WebService data service interface

Decision-making

- User information and application module management
- HTML5 display page development and running platform
- Interactive and display KDM, KKM data
- Based on graphics control, page configuration development tools
- Multiple protocol data output interfaces
- User information repository
- App1, App2, App3, ... Appn
- Browser client integration application portal
- BS backend service
- Update and verification module
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The future architecture of IIOT should be like a galaxy.
Huge volume data is not using

- Defect list: 500 million
- Replacement list: 30 million
- Device connected: 1000 million
Defect list, replacement list, maintenance record

Using data from defect list, replacement list and maintenance record to verify model

Keep feeding operation data to tuning model parameter
AI starts in the flow enterprises, which is important in China
Intellectualization will optimize and restructure the ecology of industry

- Optimize design and maintenance
- Optimize the maintenance organization
- Optimize supplement of materials and accessories, reduce inventory
- Optimize the insurance industry
- Restructure the ecology of manufacture
The relationship between AI and the fourth industrial revolution

AI has passed the age of 1-3, which is the most different but most importance period, such period shall be completed by the industry.

The new generation of industrial internet shall extensively adopt the technology of AI

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<th>4th</th>
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<td>Mass production, assembly line, electricity</td>
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Mechanization, water power, steam power

Mass production, assembly line, electricity

Computer and automation

Cyber Physical Systems

蒸汽机—机器取代人力

电器化—实现大规模生产，生产线

计算与自动化

信息物理系统（CPS）—工业互联网
融合・协作・共赢
共同把握工业互联网的历史机遇

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