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CHINA ELECTRIC POWER RESEARCH INSTITUTE

Big Data in Urban Power Distribution and Consumption Systems

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Agenda

I Perspective on Utility Big Data

II Overview of CEPRI’ s Research

III Data Analytics in Power Distribution and Consumption Systems

III Application of RMT in data analytics

Smart Grid Big Data Characteristics

Smart grid big data have the characteristics : large volume, great varieties and high velocity , and heterogeneous

- ◻ To smarten power systems, many monitoring ,metering and controlling systems have been deployed
- ◻Power system is more open to the outside world due to customers' active engagement and RES integration

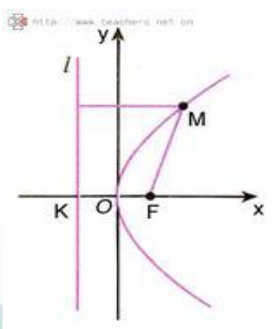
- More than 400 million smart meters have been deployed in SGCC service area

- DMS, AMI
- Power Market Systems
- GIS, PMS,
- Weather Forecast System
- EV Charging and Swapping Network Management System
- EMS, WAMS
- … …

What to Do with Smart Grid Big Data?

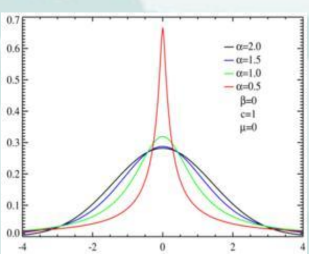
- The core of big data is data driven based method
- Suitable for statistical law and more suitable for chaos law

Constant Rule

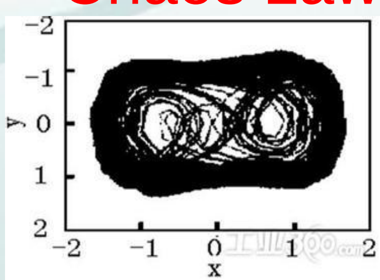


Physical model based method, limited data are needed.

Statistical Law



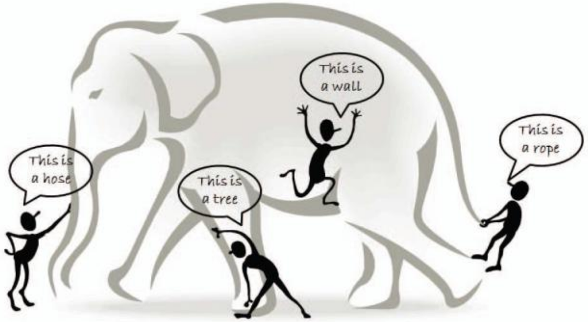
Chaos Law



Data driven method, enough data or more data are needed,

What we are doing with big data

- Based on fusion data from different sources , to apply advanced computer technologies , data mining methods to get new solutions, enabling us to see power grid with a new and comprehensive angle of view
- To apply new data driven method (deep learning , RMT, etc)



Complement to traditional method

Physical Model Based	Data-driven based method
Based on hypothesis and simplifications	Based on data reflecting genuine characteristics
Need to know mechanism/physical characteristics	Don’t need to know mechanism

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Overview of CERPI Research

➢ CEPRI initiated research on big data in 2014

Strategy

- Application requirement analysis and scenario design
- Develop big data roadmap for SGCC and CEPRI

Platform

With 84 nodes; with open source components including Hadoop, Storm, Spark, integrated

Application

- Distribution network operating efficiency and supply capability analysis
- Distribution transformers overloading warning

New theory and Method

- RMT application

Analysis on Operating Efficiency and Supply Capability

Analysis on Distribution Network Operating Efficiency & Supply Capacity

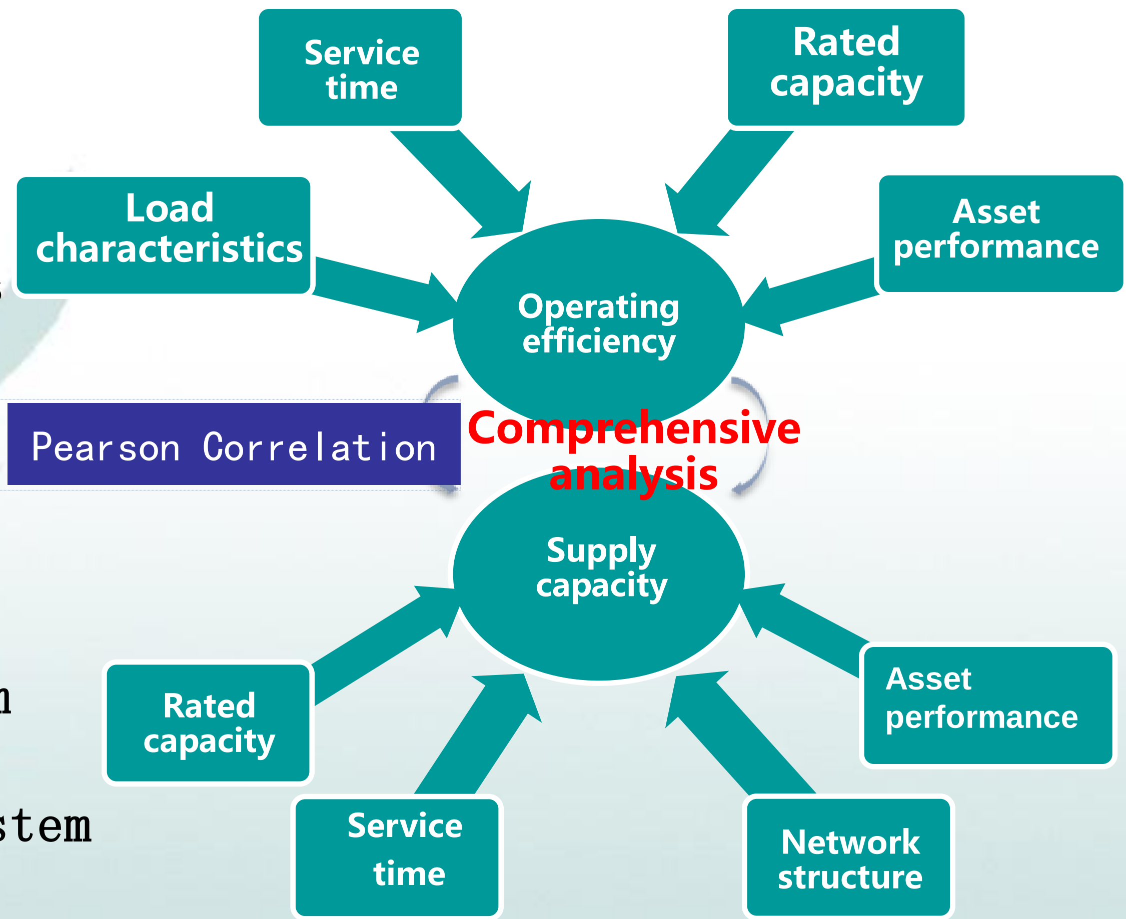
data volume : 2TB

- **50000 35~110kV Lines**
- **47000 35~110kV transformers**
- **190000 10kV lines**
- **4.72 million 10kV transformers**
- **41.3 billion loads' data**

Clustering-K-mean clustering and

Pearson Correlation

Data come from 331 cities



- ☐ Advanced Metering Infrastructure
- ☐ Business and Sales System
- ☐ Dispatching System
- ☐ Production Management System
- ☐ Power Quality Monitoring

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Analysis on Operating Efficiency and Supply Capability

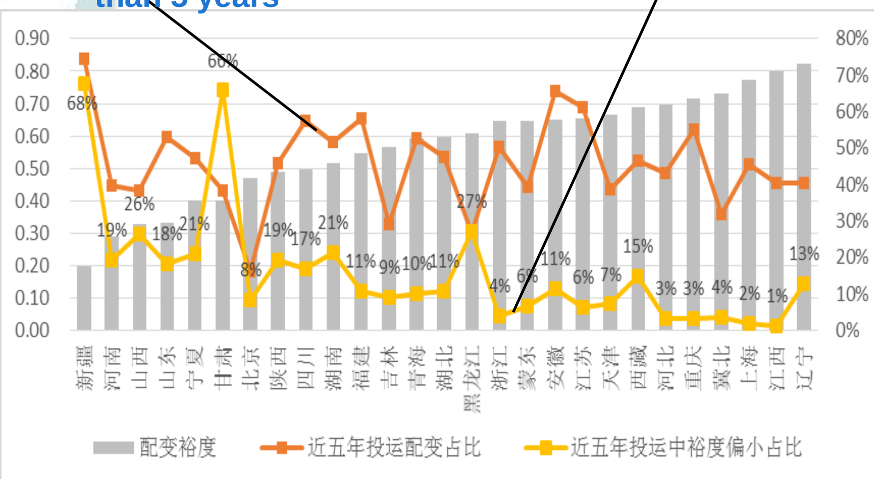
Supply Capacity Reservation VS Service Time

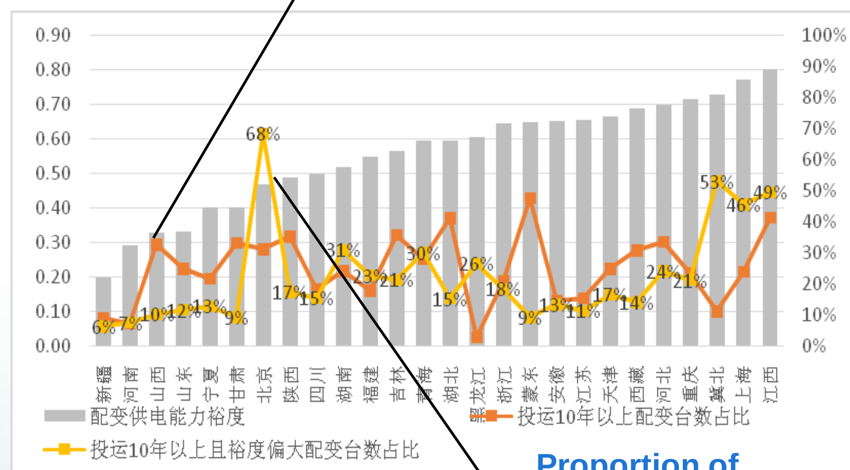
two groups of apparatuses were chosen : 1） put into operation in recent five years ; 2） have been operating for more than 10 years

Proportion of transformers less than 5 years

Proportion of transformers with low supply capacity margin

Proportion of transformers more than10 years





Proportion of transformers with high supply capacity margin

49% of distribution transformers were put into operation in recent five years and 12% of them have lower supply capability reservation. 23% of have been operating for more than 10 years, 19% of them still have larger supply capability reservation

Analysis on Operating Efficiency and Supply Capability

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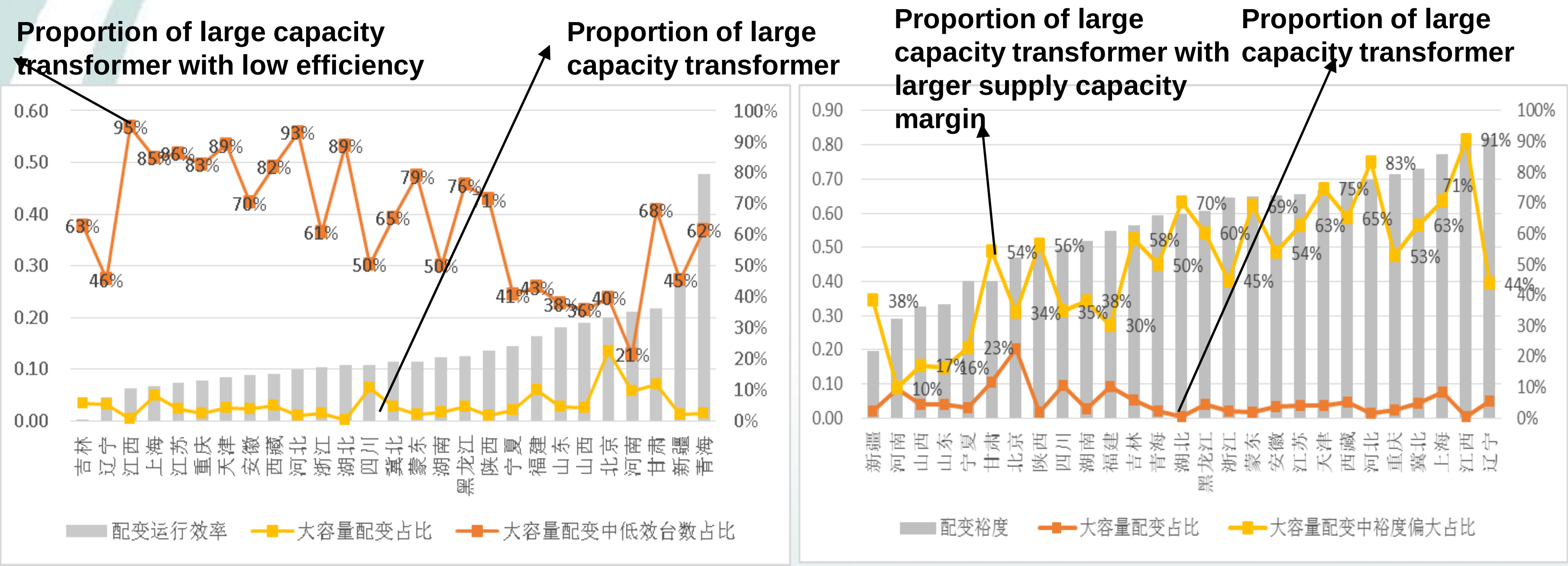
Operating Efficiency & Supply Capability Reservation VS Rated Capacity



Large capacity distribution transformers account for 5%， 55% of them have lower operation efficiency , and 40% of them have too large supply capability reservation

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Analysis on Operating Efficiency and Supply Capability

Analysis on Distribution Network Operating Efficiency and Supply Capacity

Power Supply	Operating Efficiency	High Voltage Lines	Primary transformer	Medium Voltage Line	Distrib. Transformer
<0	0-0.1	0.59%	0.26%	0.46%	1.70%
	0.1-0.5	10.81%	10.12%	11.45%	8.48%
	>0.5	11.18%	26.05%	11.18%	3.26%
0-0.5	0-0.1	2.35%	0.82%	1.81%	6.91%
	0.1-0.5	29.18%	24.53%	30.95%	19.22%

Big peak-valley difference, short time peak load ,result in insufficient power supply capability reservation and low operating efficiency, it sh

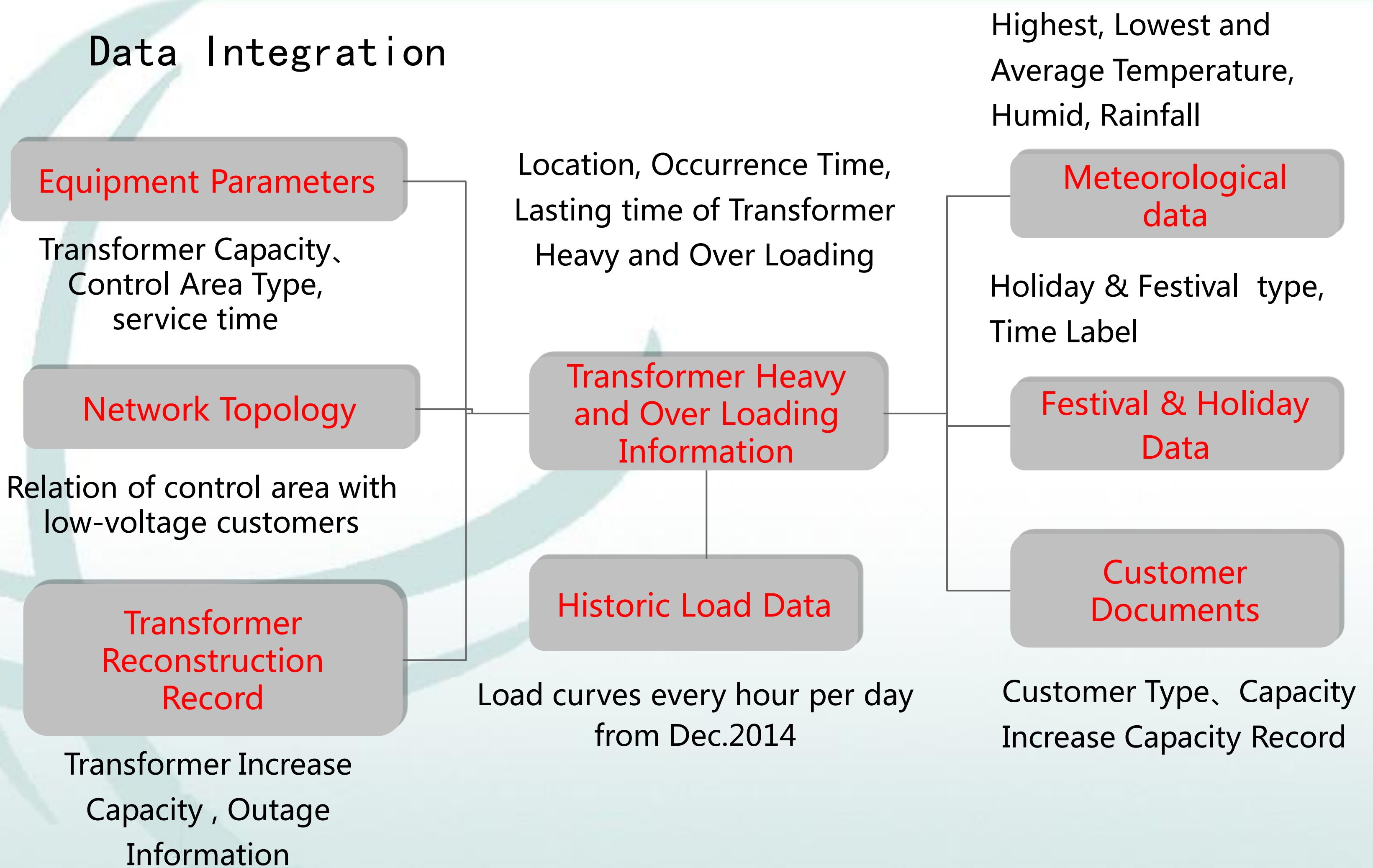
Long term under-loading leads to too large supply capability reservation and low operating efficiency. Lower operating efficiency and larger supply capacity margin coexist widespread, reflecting leading investment

Analysis on Operating Efficiency and Supply Capability

Analysis on required investment （billion RMB Yuan）

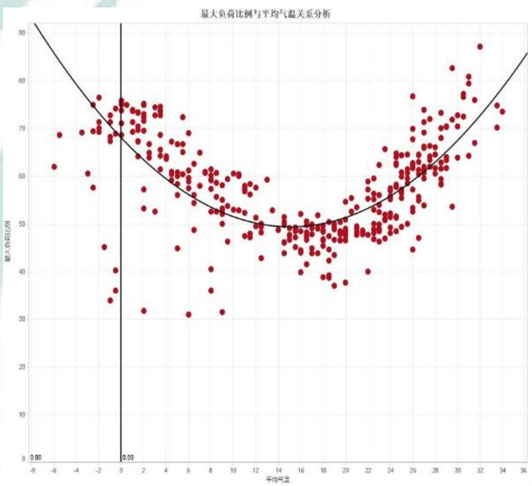
margin	equipment	Average load increment	Supply capability increment	Supply capability increment requirement	gap	13rd five year investment planning	Additional investment
0.3	HV line	6.80%	5.55%	3.80%	-1.75%	189.4	-
	Primary transformer		6.81%	6.80%	-0.01%	238.7	-
	MV lines	6.30%	3.94%	4.17%	0.23%	155.1	9.1
	Distribution transformer		4.96%	-1.62%	-6.58%	211.8	-

Transformer Overloading Prediction & Warning

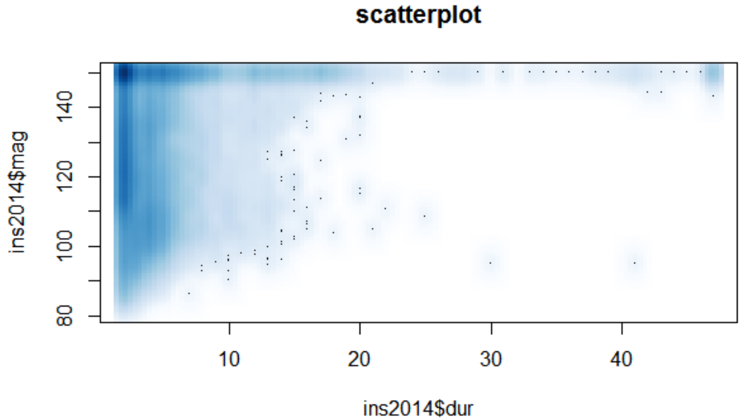


Transformer Overloading Prediction & Warning

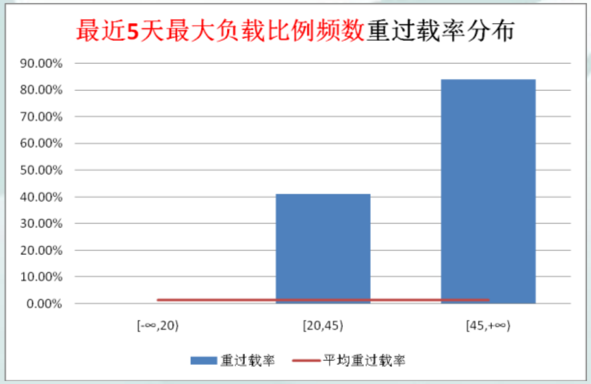
Feature Analysis for Heavy & overloading



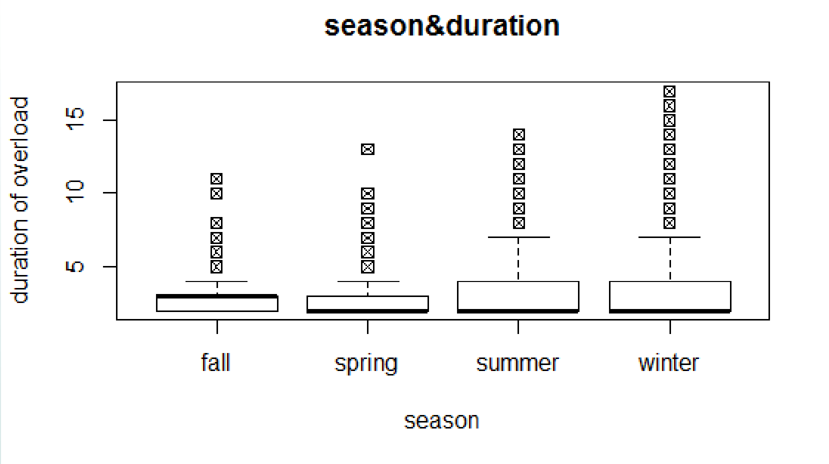
Overloading with temperature



Overloading period with overloading degree



Overloading with historic loadability



Overloading with seasons

Forecast model by regression

$$y = k_1 * C_1 + k_2 * C_2 + \ldots + k_n * C_n$$

overloading probability

feature parameters representing influence degree ,obtained by sampling training

characteristic variable

Transformer Overloading Prediction & Warning

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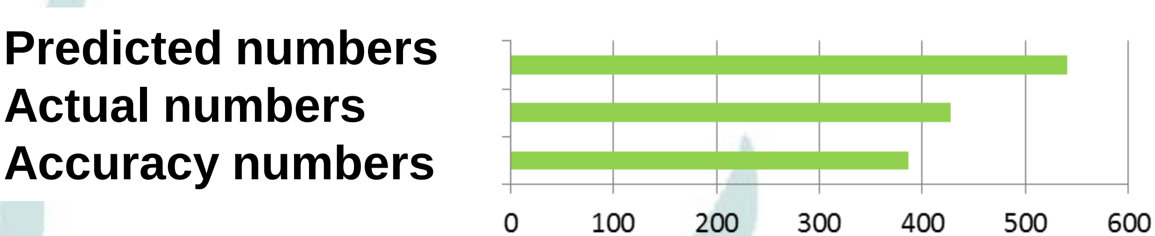
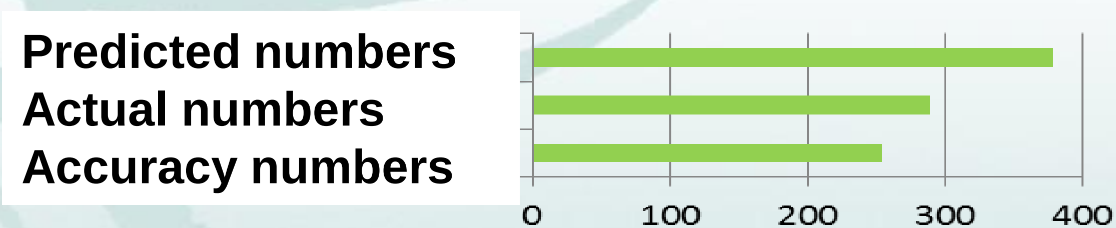
Prediction Results

Prediction for January 1st, 2016



Prediction accuracy： 71.66%

Prediction for 2015 Spring Festival Holidays



Prediction accuracy： 67.01%

Transformer Overloading Prediction & Warning

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Application Implementation in the platform

Overloading warning shown at GIS platform

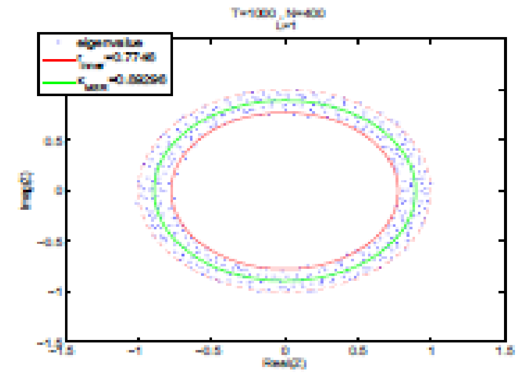
Influence factor analysis for single overloading transformer

Application of RMT in Big Data Analytics

- Massive data can be represented by random matrix .
- When the dimensions of a random matrix are sufficiently large , the random matrix conforms to some rules, for example:
  - The Single-Ring Law

$$X_{N\times T} = \left[x(t_1), x(t_2), \cdots, x(t_i), \cdots\right] \in C^{N\times T}$$

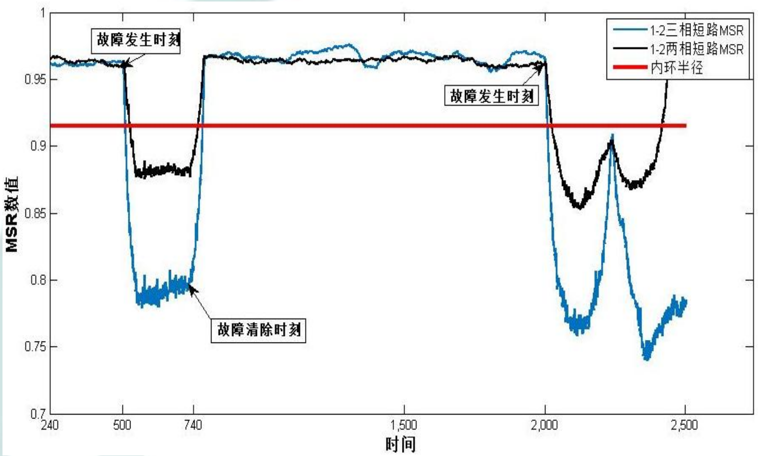
- To calculate covariance matrix $S_n = \frac{1}{n}\sum_{i=1}^{n} x_i x_i^T$
- To get singular value equivalent matrix $X_u = U\sqrt{XX'}$

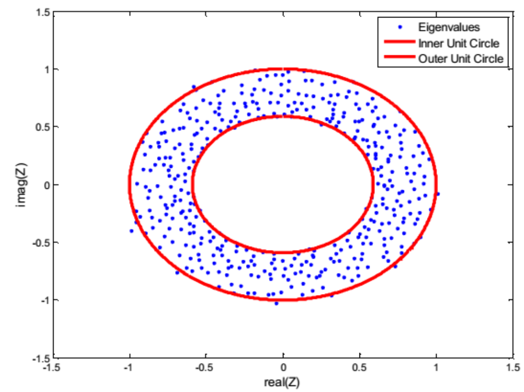


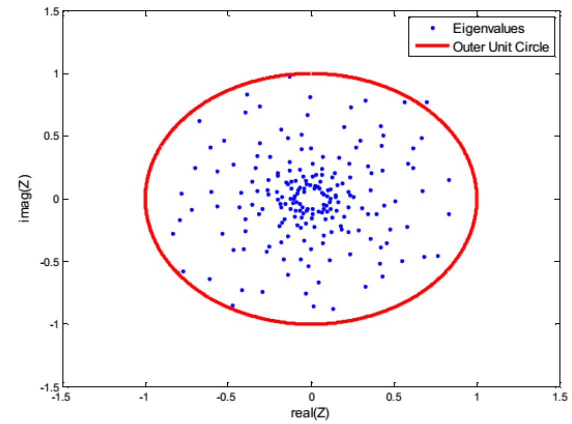
- To get matrix Z $z_i = \frac{x_i}{\sqrt{N}\sigma(x_i)} \quad (i = 1, 2, \ldots, N)$ $\quad E\left(z_{i,j}\right) = 0, \sigma^2\left(z_{i,j}\right) = 1/N$
- The ESD (Empirical Spectrum Distribution) of Z

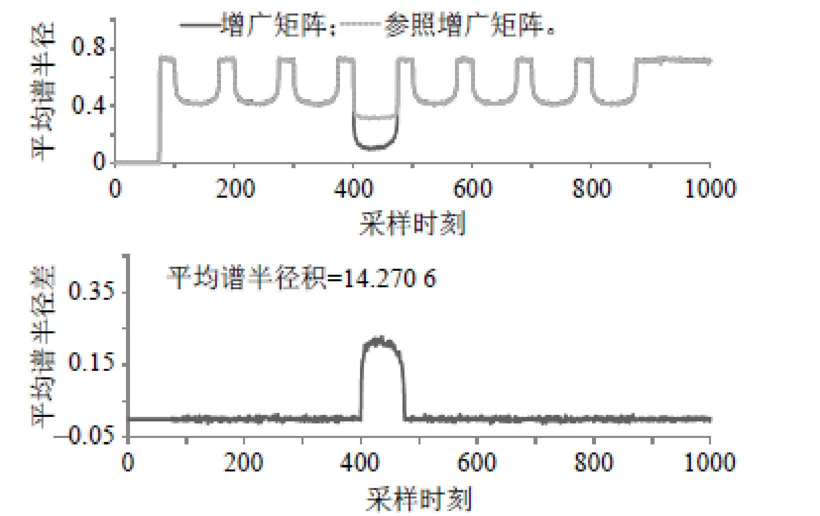
$$f(\lambda) = \begin{cases} \frac{1}{\pi c L}|\lambda|^{\frac{2}{L}-2} & (1-c)^{\frac{2}{L}} \le |\lambda| \le 1 \\ 0 & 其他 \end{cases} \qquad c = N/T$$

Application of RMT in Big Data Analytics









节点号	采样时刻	负荷/kW	采样时刻	负荷/kW
18	$t_s=1\sim400$	90	$t_s=401\sim1000$	135
	$t_s=1\sim100$	60	$t_s=101\sim200$	66
	$t_s=201\sim300$	72	$t_s=301\sim400$	78
33	$t_s=401\sim500$	84	$t_s=501\sim600$	90
	$t_s=601\sim700$	96	$t_s=701\sim800$	102
	$t_s=801\sim900$	108	$t_s=901\sim1000$	108
其他	$t_s=1\sim1000$		不变	

Barriers

- Difficulty in getting data due to concern about security or privacy
- Difficulty in data fusion from different silo systems
- Complex in technologies, cooperation among multi-disciplinary experts is required, short of methodology
  - ....

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Thank you!