IOP Conf. Series: Materials Science and Engineering **199** (2017) 012066 doi:10.1088/1757-899X/199/1/012066

Construction and Application of Theoretical Line Loss Calculation Platform for 220 kV and above Power Grid in Shanghai

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Abstract. Instead of drawing power grid and inputting component parameters manually to establish calculation model, the theoretical line loss calculation platform for 220 kV and above power grid in Shanghai is developed based on grid dispatching D5000 system, capable of capturing real-time power grid basic / operational data and offline graphics saving. It resolves all data for previous day automatically before commencing theoretical line loss calculation. The theoretical line loss calculation results for 500 / 220 kV showed its validity and accuracy. The project effectively accumulates the scientific data and promote State Grid Shanghai Municipal Electric Power Company to fully grasp the related equipment operating conditions of Shanghai 500 / 220kV power grid. The analysis results not only help power company to guide production practice, but also provide a better understanding for power grid weakness and loss composition, which enables power company managers to guide future construction and transformation of power grid accurately and effectively.

1. Introduction

According to the deployment of Shanghai municipal committee and government, as the city's largest energy supply enterprises, State Grid Shanghai Municipal Electric Power Company is shouldering a very important economic, political and social responsibility for energy-saving in Shanghai. The line loss refinement project provides technical support to reduce losses for the 13th national five-year plan. 220kV and above power grid loss calculation for each line and sub-regional is achieved by the application and implementation based D5000 system. The problems existing in the original system and the causes of unreasonable line loss are found out through comparing actual value with theoretical value, which provide the basis for line loss management of 220kV and above power grids.

The project will effectively accumulate the scientific data and promote State Grid Shanghai Municipal Electric Power Company to fully grasp the related equipment operating conditions of Shanghai 220kV and above power grid. The analysis results not only help power company to guide production practice, but also provide a better understanding for power grid weakness and loss composition, which enables power company managers to guide future construction and transformation of power grid accurately and effectively. The program will also provide scientific basis for the quantification index and decision-making, such as planning and design for power loss reduction , development of targeted measures, reactive power optimization and loss reduction implementation for power grid.

2. Technical solutions

2.1. Technical features

The common methods of domestic theoretical line loss calculation are mostly carried out by drawing power grid and inputting component parameters manually to establish calculation model, which leads to increased line loss management workload and low computational efficiency when manual adjustment is required after grid operating mode changes.

The platform is developed based on grid dispatching D5000 system, capable of capturing real-time power grid basic / operational data and offline graphics saving [1]. The local theoretical line loss calculation platform will access computing graphics, network topology information, switch displacement and scheduling operation information after data capturing and graphics saving. At the same time, the local platform directly starts calculation, query, statistical functions, with the analysis and positioning function of error and abnormal data from the original system.

2.2. Platform architecture

The overall structure of the line loss management platform is divided into six parts: basic component platform, business support component, business domain model, data deepening application, SOA(Service Oriented Architecture) software platform and data warehouse platform (see figure 1).

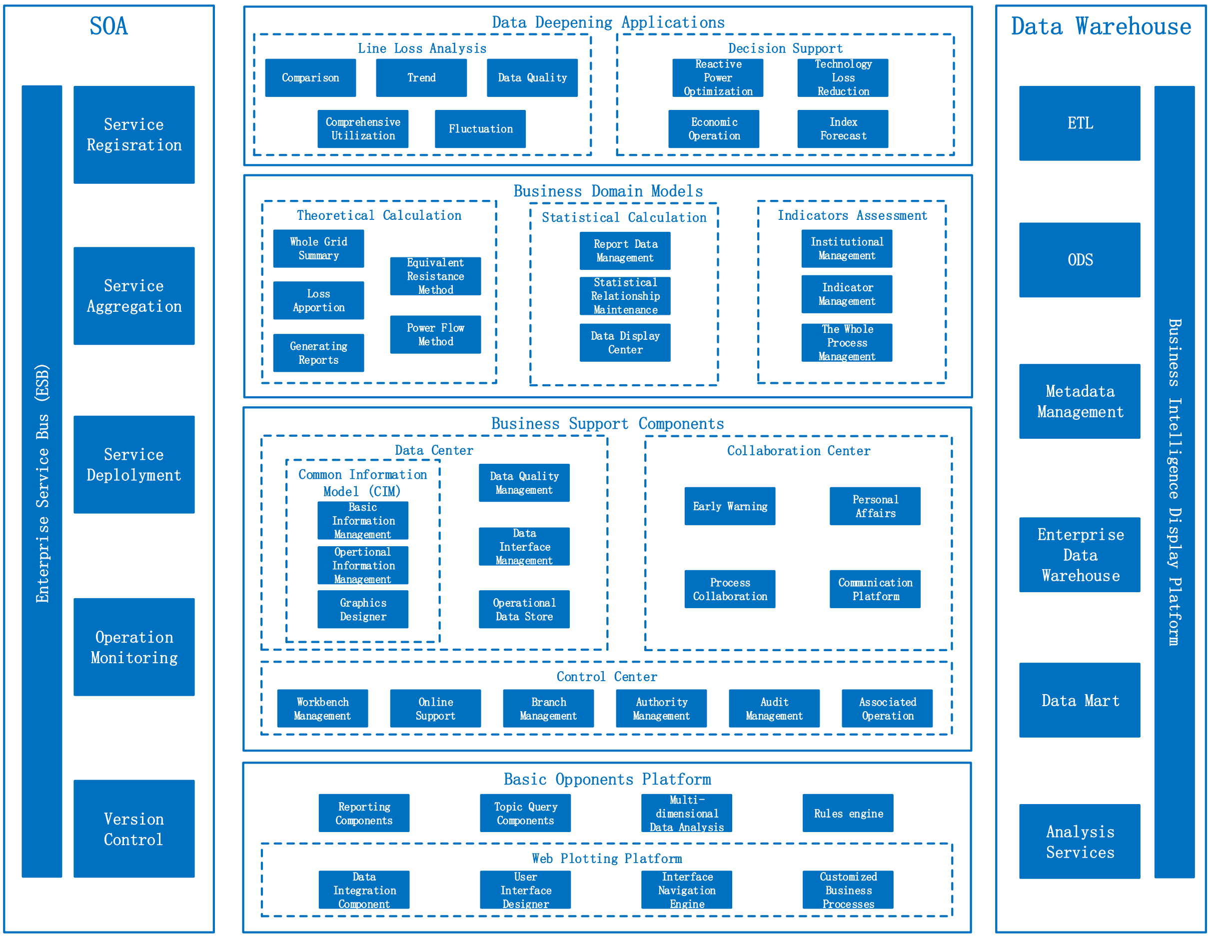

Figure 1. Theoretical line loss calculation platform architecture.

2.2.1. Hardware design. The platform hardware design is relatively simple, including two servers: database server and application server (see figure 2).

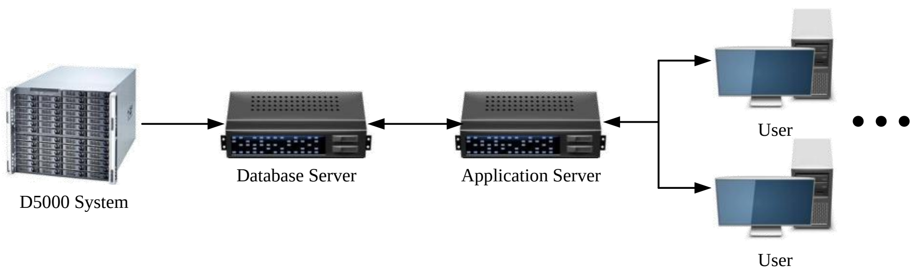

Figure 2. Platform hardware design.

*2.2.2. Data warehouse.*The data will be integrated into the ODS from the SCADA, GIS or even line loss calculation platform itself, where the data can be automatically integrated into the ODS if it complies with the IEC 61970 standard. If it is non-standard data, the platform has provided a variety of adapter interface to access it into the ODS without modifying the third-party business system structure [2]. At present, the platform has completed a variety of SG186 system adapter interface, such as NARI (Nanjing Automation Research Institute), Kedong and other SCADA (Supervisory Control And Data Acquisition) together with State Grid marketing MIS system [3]. After that, the data will be transferred into data warehouse through cache, in which the data structure will be re-reorganized to form the dimension table, the fact table, and metadata. Finally, the application system will obtain data from data mart, which can be divided into sub-topics, sub-topics and light summary, so as to realize the function of report, analysis, auxiliary decision-making and other functions for loss reduction. The design and implementation of enterprise data warehouse model is the key to success.

*2.2.3. Basic component platform.*As can be seen from the picture above, the basic components of the platform is divided into two parts, one of them is web mapping related as data integration components for data extraction, conversion and loading, plus with user interface designer, interface navigation component, data integration component and customized business process engine. The other part is graphics-independent and common technical components for report component, theme query component, multidimensional data analysis component and rule engine. These highly abstract platforms, components, and engines will be the cornerstone of the complete line loss management platform.

*2.2.4. Business support components.*With the support of the basic components, business functions such as organization, authority and etc. can be reused in accordance with the high cohesion and low coupling design principles, which enables to form business support layer including data centers for storing and managing data, collaboration centers for cross-departmental business processes and control centers for various services.

2.3. Data interface

The development of this platform is based on dispatching D5000 system, obtaining gird basic and operational data from CIM-E and .DT files respectively.

*2.3.1. D5000 system introduction.*NARI D5000 is a new generation of integrated smart grid dispatch control system adapted to unified strong smart grid construction requirements, with independent innovation and leading international level. The system coordinates the business requirements of electric power dispatching institutions at all levels by adopting basic software such as domestically produced safe operating system and security relational database [4]. It has formulated grid graphics description standard and provided standardized and efficient public services such as exchange service, model service, data service, graphic service and application service, which realizes the sharing and common maintenance of power grid model, graphics and data within the various agencies, as well as the exchange, splicing and inheritance among dispatching departments [5].

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*2.3.2. Data interface processing progress.*The platform preserve CIM-E and .DT files regularly through ftp visiting. The grid basic data using incremental updates monthly, while the operational data updates every five minutes. And It resolves all data for previous day automatically before commencing theoretical line loss calculation.

The CIM-E file is fundamental basis for theoretical line loss calculation model and it consists of grid basic data like bus bars, power lines, transformers, breakers, isolating switches, reactors, capacitors and their measuring points. The critical data for theoretical line loss calculation is shown as follow:

Line: name, voltage level, first and last nodes, topology, line parameters like R, L and B/2; Transformer: name, voltage level, relationship with line, transformer parameters capacity, idling and full load loss; Reactor / Capacitor: name, voltage level, relationship with bus bar or line, capacity.
The .DT file provides switch state, voltage, current, active power and reactive power of every measuring points, which is also critical for calculation accuracy.

3. Calculation display

3.1. A part of the entire power grid and substation inner diagram
A part of the entire power grid is shown as follow, including substations, lines, topologies and their names. And substation inner diagram is also shown as follow, including bus bars, breakers, isolating switches, reactors, capacitors topologies and their names (see figure 3).

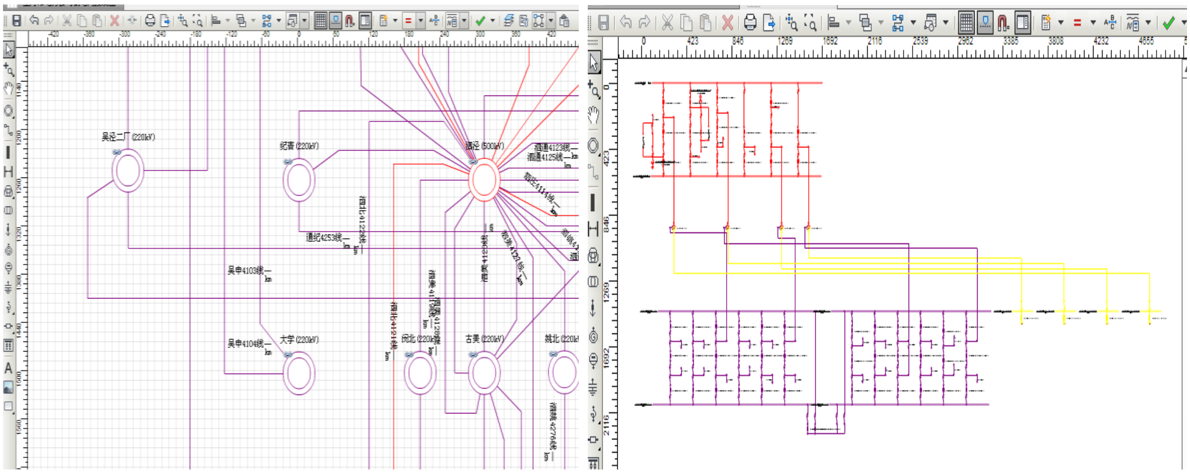

Figure 3. A part of the entire power grid and substation inner diagram.

3.2. Calculation settings
Calculation settings like method, number of iterations, permissible error, reference capacity, other loss, temperature, date and power factor can be adjusted as needed. Calculation information shows its progress and status.

3.3. Analyzed basic and operating data
Analyzed basic data is shown as follow. Line parameters like resistance, reactance and capacitance and transformer parameters like voltage level, capacity, idling and full load loss. Together with loads, generators as PQ nodes, generators as PV nodes, generators as Vθ nodes, breakers, reactors and capacitors (see figure 4).

Number	Line Name	Voltage kV	Status	Actual Value		
				Resistance Ω	Reactance Ω	Susceptance S
1	Bao Xing 2196	220	Operational	0.3756	3.1052	2.13611E-05
2	Bao Xing 2228	220	Operational	0.1904	2.1689	1.53686E-05
3	Bao Xing 2229	220	Operational	0.2275	2.1953	0.000011569
4	Chang Feng 2b25	220	Operational	0.0159	0.0635	1.7015E-07
5	Chang Feng 2b26	220	Operational	0.0159	0.0635	1.7015E-07
6	Chen Xiang 4133	220	Operational	0.4444	4.0945	4.51229E-05
7	Chen Xiang 4134	220	Operational	0.4444	4.0786	4.72779E-05
8	Chun Hua 2284	220	Operational	0.159	1.0421	0.000228091
9	Dong Dian 4229	220	Operational	0.1428	1.4865	3.23441E-05
10	Dong Dian 4230	220	Operational	0.1375	1.4918	3.26654E-05
11	Dong Lu 4227	220	Operational	0.0423	0.7036	5.71835E-06
12	Dong Lu 4228	220	Operational	0.0582	0.7089	5.93575E-06
13	Dong Gang 2137	220	Operational	0.1904	2.1689	1.44613E-05
14	Dong Gang 2220	220	Operational	0.201	2.1795	1.61815E-05
15	Dong Jia 2125	220	Operational	1.0104	5.5598	1.89792E-05

Figure 4. Analyzed power lines basic data.

Analyzed basic and operating data is shown as follow. As active and reactive power known for PQ nodes, active power and voltage known for PV nodes, voltage and phase angle known for Vθ nodes (see figure 5).

Number	Substation Name	Load Name	Voltage kV	0:00	1:00	2:00	3:00	4:00	5:00	6:00
1	Bai Dong	Mu Bai 4298	220	59.7062	59.7062	59.0093	59.9386	60.1709	60.1709	60.6355
2	Bai Dong	Mu Bai 4299	220	50.4134	54.3629	54.8275	57.6154	57.1507	57.1507	57.1507
3	Bao Bei	1#	35	6.98445	6.79031	6.50166	6.49294	4.355	4.72885	7.25447
4	Bao Bei	1#	110	0.515421	-0.996338	2.15428	3.17445	4.31475	-5.09343	-2.38739
5	Bao Bei	2#	35	5.17327	5.17361	4.73466	4.70791	3.85718	4.06055	4.97306
6	Bao Bei	2#	110	3.78116	2.73805	5.06962	10.6112	7.82117	-1.37382	-0.744133
7	Bao Bei	1#	35	2.27094	0.536215	-0.406834	0.374759	1.4564	1.81396	3.72738
8	Bao Bei	2#	35	4.98271	4.62981	3.28151	3.84214	4.12839	4.6193	4.96819
9	Bao Bei	3#	35	0	0	0	0	0	0	0
10	Bao Bei	3#	110	0	0	0	0	0	0	0
11	Bao Neng	Bao Xing 2100	220	195.2	200.7	200.7	191.3	197.8	202.3	195.5
12	Bao Neng	Bao Xing 2196	220	18.4194	37.3802	31.9344	50.2038	11.7984	38.2181	38.4862
13	Bao Neng	Bao Xing 2228	220	189.613	240.295	225.479	247.046	178.997	239.697	239.793
14	Bao Neng	Bao Xing 2229	220	196.268	235.208	219.801	243.884	171.614	236.122	238.941
15	Bao Liu	1#	35	24.752	21.882	20.517	19.488	18.886	18.802	20.552

Figure 5. Analyzed load operational data.

3.4. Calculation results

The calculation results for power lines and transformers are shown as follow (see figure 6).

Line Name	Voltage kV	Electricity Supplied mWH	Reactive Power	Active Power Loss mWH	Active Power Loss Ratio %
Bao Xing 2196	220	1,485.5148	9.0163	2.7114	0.18
Bao Xing 2228	220	2,126.8952	22.6725	2.8366	0.13
Bao Xing 2229	220	2,101.8442	24.5716	3.2984	0.16
Chen Xiang 4133	220	115.3113	-28.5376	0.0584	0.05
Chen Xiang 4134	220	115.8253	-29.9241	0.0588	0.05
Chun Hua 2284	220	409.6765	-143.5222	0.0861	0.02
Dong Dian 4229	220	1,728.9938	-5.6015	1.4244	0.08
Dong Dian 4230	220	1,724.1680	-5.8464	1.3628	0.08
Dong Lu 4227	220	3,017.4395	17.5619	1.2729	0.04
Dong Gang 2137	220	212.6838	-9.0652	0.0283	0.01
Dong Gang 2220	220	211.4390	-10.1837	0.0296	0.01
Dong Jia 2125	220	275.4355	-11.0348	0.2401	0.09
Dong Jiao 2123	220	520.3576	-23.9521	0.9481	0.18
Dong Jiao 2124	220	502.9044	-24.6279	0.5470	0.11
Dong Tian 4231	220	230.6870	-14.2492	0.0195	0.01

Figure 6. Power line loss calculation results.

And theoretical line loss rate trends for July 2016 is shown as follow. The constant loss (transformer iron loss) is almost fixed, while the variable loss (line loss and transformer copper loss) follows the changes of day load, presenting positive correlation basically. Too light or heavy load will both leads to high loss rate (see figure 7).

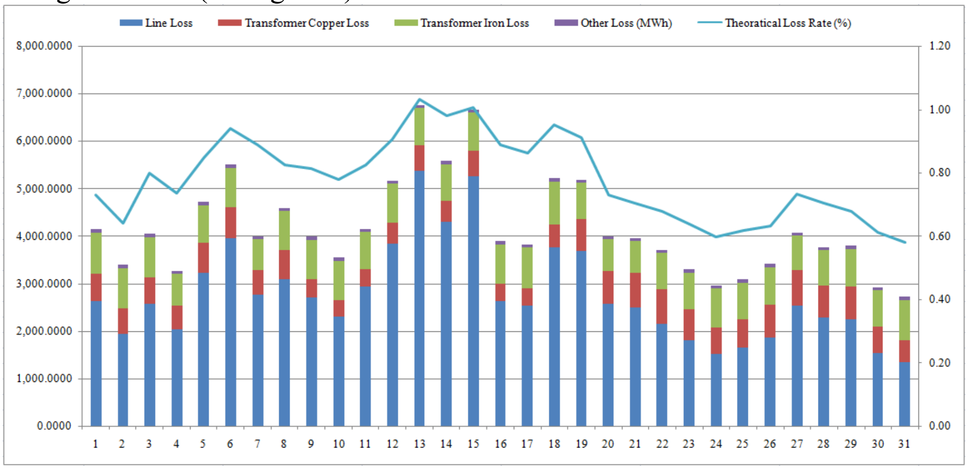

Figure 7. Theoretical line loss rate trends for July 2016.

4. Calculation result analysis

4.1. 500kV layer results

The theoretical calculation results for 500kV voltage level line loss of the whole power grid on the representative day this year (August 5, 2016) and previous year (July 29, 2015) are shown as follow (see table 1):

Table 1. 500kV voltage level theoretical line loss calculation results comparison.

	Electricity supplied	Energy Loss (MWh)						Theoretical loss rate(%)	Copper : iron ratio
		1 Line loss	2 Transformer		3 Energy used by substation	4 Other	Total		
			Copper	Iron					
2016.8.5	336780	632	190	188	8	29	1047	0.31	1.02
2015.7.29	377070	835	231	178	8	41	1294	0.34	1.30
Change	-40290	-202	-41	10	0	-13	-246	-0.03	-0.28
Percentage	-10.69	-24.22	-17.73	5.35	1.21	-30.53	-19.03	/	/

In terms of 500kV variable loss, the line and transformer copper loss reached 632MWh and 190MWh on the representative day this year (August 5, 2016) forming a decrease of 202MWh and 41MWh (-24.22% and -17.73%) comparing previous representative day last year (July 29, 2015) as 835MWh and 231MWh.The main reason is that the electricity supply within 500kV scored 336780MWh on the representative day this year, accounting for 89.13% of previous representative day as 377070MWh.It indicates the overall load level within 500kV has declined comparing previous representative day, which led to a decrease in the variable loss (line and transformer copper losses). The maximum temperature only reached 33.3 ℃ and the weather is cloudy with thunderstorms, which is 5 ℃ lower than the highest temperature of 38.8 ℃ on previous representative day last year causing relatively light load. In terms of 500kV constant loss, the transformer iron loss reached 178MWh on the representative day this year (August 5, 2016) forming a increase of 10MWh (+5.35%) comparing previous representative day last year (July 29, 2015) as 178MWh due to adding 2 500kV operational transformer after Yanghang partition combing project completed, realizing east/west fragment independent operation (see table 2).

Table 2. 500kV voltage level theoretical line loss calculation results allocation.

Theoretical line loss Rate (%)	>1.0	0.5-1.0	0.2-0.5	<0.2	≥Average Value (0.14)	Total
The number of lines	0	1	4	33	11	38
Percentage of number (%)	0.00	2.63	10.53	86.84	28.95	100.00
Energy Loss	0.00	84.48	256.65	291.14	448.24	632.27
Percentage of loss (%)	0.00	13.36	40.59	46.05	70.89	100.00

4.2. 220kV layer results

The theoretical calculation results for 500kV voltage level line loss of the whole power grid on the representative day this previous year are shown as follow (see table 3):

Table 3. 220kV voltage level theoretical line loss calculation results comparison.

	Electricity supplied	Energy Loss (MWh)						Theoretical loss rate(%)	Copper : iron ratio
		1 Line loss	2 Transformer		3 Energy used by substation	4 Other	Total		
			Copper	Iron					
2016.8.5	445280	1037	328	673	27	42	2107	0.47	0.49
2015.7.29	487220	1369	412	655	27	56	2519	0.52	0.63
Change	-41940	-332	-84	18	0	-14	-412	-0.04	-0.14
Percentage	-8.61	-24.27	-20.35	2.76	0.35	-25.06	-16.35	/	/

In terms of 220kV variable loss, the line and transformer copper loss reached 1037MWh and 328MWh on the representative day this year (August 5, 2016) forming a decrease of 332MWh and 84MWh (-24.27% and -20.35%) comparing previous representative day last year (July 29, 2015) as 1369MWh and 412MWh.The main reason is that the electricity supply within 220kV scored 445280MWh on the representative day this year, accounting for 91.39% of previous representative day as 487220MWh.It indicates the overall load level within 220kV has declined comparing previous representative day, which led to a decrease in the variable loss (line and transformer copper losses). Also the cool weather In terms of 220kV constant loss, the transformer iron loss reached 673MWh on the representative day this year (August 5, 2016) forming a increase of 18MWh (+2.76%) comparing previous representative day last year (July 29, 2015) as 655MWh due to adding 10 220kV operational transformers as 7 newly built and 3 increased capacity summing 2520 MVA new capacity. The increased number of 220KV operational transformer directly caused the increase in transformer iron loss. Meanwhile, cable lines are highly concentrated in Shanghai 220kV voltage level with high capacitive effect. The capacitive reactive power is constantly transmitted from 110kV and lower voltage level, which leads to higher system voltage within over 75% of all 220kV substations and brings difficulty to transformer iron loss management. and temperature caused relatively light load (see table 4).

Table 4. 220kV voltage level theoretical line loss calculation results allocation.

Theoretical line loss Rate (%)	>1.0	0.5-1.0	0.2-0.5	<0.2	≥Average Value (0.11)	Total
The number of lines	2	5	27	367	126	401

percentage of number (%)	0.50	1.25	6.73	91.52	31.42	100.00
Energy Loss	66.29	131.90	223.27	615.39	784.79	1036.84
Percentage of loss (%)	6.39	12.72	21.53	59.35	75.69	100.00

5. Platform construction experience summary

5.1. Establishing standardized CIM models
The platform has established standard CIM models in accordance with IEC 61970 standard based on the principles of unified coding, model, data dictionary and interface. At the same time, a multi-dimensional analysis model is established, which supports OLAP(Online Analytical Processing), ad hoc report and data mining proving unified data access services.

5.2. Automatic Graphics Modeling
The platform can automatically generate CIM models from grid topology source system data and create wiring diagrams based on standard CIM models, providing automatic synchronization of CIM models to support the real-time grid topology updating from the source systems, which helps to reduce basic data maintenance workload considerably.

5.3. Achieving graphical modeling platform and business applications based on B/S structure
The platform adopts complete B/S structure, making full use of Web2.0 and RIA (Rich Internet Applications) technology, achieving graphical modeling in web pages. The user can directly input or modify equipment parameters, operational and other types of grid model data.

5.4. Improved data quality management
Line loss management platform provides a wealth of data quality management rules on the basic data (static data) and operational data (dynamic data) for quality screening and correction management to ensure its accuracy, consistency and integrity.

5.5. Realizing report customization and graphical display of results
The platform achieves the report/table format and data content customization through built-in sub-theme ODS (Operational Data Store) data set definition. Customers can freely define various reports and queries without having to master complex database queries such as associative queries and stored procedures. The platform enables user to acquire their concerned calculation results and other information in the wiring diagram in a intuitive and customized way.

References
[1] Yang Fan, Liu Jun, Lu Bingbing, Design and application of integrated distribution network line loss analysis system, *2016 China International Conference on Electricity Distribution (CICED)* pp 1-4
[2] Yang Fan, Liu Jun, Si Wenrong, Xu Li, Research on theoretical line loss calculation of low-voltage power distribution area in Shanghai, *2014 China International Conference on Electricity Distribution (CICED)* PP 119 - 122
[3] LI Zhanchang, ZHAO Fusheng, Calculation of net loss in power system by scada, Power System Technology, Vol. 24 No. 7, pp 37-40
[4] YIN Zili, QIAN Jing, CHEN Yuxing, Dispatching/Distribution Integration Technology Scheme Based on D5000 Platform, Automation of Electric Power Systems, Vol. 40 No. 18, pp 162-167
[5] HU Li-qing, ZHAN Zhen-bin, YU Hong, Research and application of power system state estimation debugger based on the D5000 model and the cross-section, Energy Engineering, 2016(06), pp 23-25