Preface

China needs to solve issues in energy sources, environmental protection and electric power reform by making scientific energy sources planning. For electric power department, scientific energy sources planning means the approach to meet the speedy growing electric power demands by using effective economic and analytic measures and the least total social cost. We refer this series of analytic measures and the process using such measures to educe the key control data for electric power planning as the Least Total Social Cost Scientific Electric Power Planning, or the scientific electric power planning.

In China, many important aspects of the current measures, process and outcome of planning can not match with the scientific electric power planning, and the new pattern of multiplied electric power main body created during the progress of electric power system market reform has taken away the systematic basis that traditional electric power planning has been relying on, which makes it so exigent to create a new series of scientific electric power planning. The Energy Foundation of America has been paying attention on the electric power scientific planning and has organized fundamental research. Entrusted by the Energy Foundation, China Electric Power Development and Promotion Association made systematic and unitary research on scientific electric power planning and educed some result. During the research, China Electric Power Development and Promotion Association received guidance from many industrial experts; officers from the Energy Foundation and the State Electricity Regulatory Commission of China provided directive advice, energy sources expert in America, Mr. David Moskovitz also made some pertinent suggestions. We would like to express our gratitude for all of their help.

1. Concept of Scientific Electric Power Planning

Electric power industrial planning in China was resulted from the help of former Union of Soviet Socialist Republics (USSR) experts dated back during the early years of the foundation of PRC, a 3-year-recover plan was made in early 50's of last century; started from 1952, targeting 156 construction items helped by USSR, the former Ministry of Fuel Industries made the 1^{st} 5-year plan under the guidance of USSR experts. Eleven 5-year plans have been made and executed since then, which have effectively guaranteed the development of electric power industry. However, the methods and principles of such plans were of the attributes of planned economy, along the progress of electric power systematic reform, these attributes can no long adapt the needs of market economy. In order to find out the origin of such problems and propose new planning theories, the research on planning must start from the very beginning.

1.1 The Characteristic of Electric Power Planning

There are many significant differences between electric power planning and other planning:

First, electric power is an industry requires the timely balance between production and demand, electric power planning must consider this fact. Different power supply structures cause different supply characters, various electric power consumers make the consumption characters change all the time, which makes electric power planning a specific work that has strong technical nature. Production must exceed demand, the exceeded part is called reserve, and electric power planning can be said as the reflection of choosing the reserve.

Second, multiple targeted. A qualified electric power planning should targeted on the society, the government and individuals, e.g. industrial growth, reasonable profit, sufficient market guarantee, the control over crucial industries, quality & safety, research & technical development, environmental protection, enterprises' social responsibilities, credit, risks, and etc.

Third, the uncertainty of planning's boundary. Since electric power planning is connected to the society, power suppliers and supplying conditions, the change on each element within any of them may affect the result of electric power planning, plans must be emended timely.

Fourth, the hierarchy of planning. The hierarchy of planning rooted from the hierarchy of grid. Manage the grid by different areas and hierarchies is one of the major measures to guarantee system's safe operation which has been recognized by many countries in the world.

1.2 Main Contents of Electric Power Planning

After more than 50 years of research and practice, the content, work flow and approval process of traditional electric power planning have become stable, and all kinds of regulations, guidelines, principles, methods have been written and recorded in history. The main contents of electric power planning include;

--analyze the current situation of electric power system, especially the exiting or potential issues of the grid, and problems that need to be solved in the next planning period.

--electric power demand forecast, which is the fundamental work and basis for electric power planning.

--power supply planning, which proposes each benchmark year, total installed capacity, layout, structure, timeline and corresponding conditions that will meet the demand for electric power.

--grid planning, mainly include the planning for transmission and distribution network, and plan network structure according to power supply layout and load demand.

--networking, which is the main measure to economize the grid.

--choose unit type and line structures.

--progress of external conditions, such as the supply of key facilities, energy saving plans and etc.

--environment evaluation, to pass the evaluation carried by environmental protection department.

--funding and economic profit evaluation.

--grid’s static and transient stability calculation or computer simulation.

--human resource planning and etc.

The above mentioned 11 aspects can be various in different locations, however it is the result of years of practice and they contributed in the history of China’s electric power development. Scientific electric power planning should keep the effective parts of traditional planning, while the content, methods and mechanism must be innovated during the market reform of China’s power system.

1.3 Main Issues of Electric Power Planning in China

1.3.1 The Narrow View of Electric Power Planning

Electric power is an industry which tightly connected to economy and society, the application degree of electric power is a major index that reflects how developed the society is. Traditional electric power planning focuses more on the internal relationship, which is relatively narrow, and the following contents were not considered:

1. The interaction of the environment, elements like exhaust gas, waste water, waste residue, noises, water zoology and etc can be the restriction for electric power in seeable future.
2. The close connection between the safety of electric power and the stability of the society and other industries, therefore electric power enterprises need to be guided to maintain the investment on supply’s reliability so as to keep safe production in a rather high level.
3. The substitution between electric power and other energy. China’ energy efficiency remains in a low level mainly due to the low proportion that electric power occupies in all energies and the target of planning is to raise this proportion. Meanwhile, new energy such as wind power, solar energy and biological energy need to be considered in the middle or long run.
4. Lack of organic connection between planning and project standard. Problems such as focusing on project over planning, disconnection between project investment and the market, low investment benefit, loose obligation on investment risks have obsessed the healthy development of electric power for a long time.
5. The impact of planning and energy saving measures on electric power, to introduce Demand Side Management (DSM) into electric power planning and make the energy saved in the demand side to be a kind of new source.
6. To consider other social targets, such as the affect of electromagnet and noises, the universal services of electric power supply, the impact on environment and zoology from power plant and grid.

1.3.2 Ineffective Adjustment on Industrial Structure, Consumption and Environment Improvement

The contradictions in electric power industrial structure are the lagged grid construction than supply construction, unreasonable supply structure where middle and small sized units occupy a large proportion, small ratio of high quality clean energy, and high thermal power plants' average power supply consumption, where half of total sulfur dioxide emission in the country comes from these plants.

1.3.3 Long time Inferior Economic Benefit

The net rate of return on total assets of electric power industry is lower than the nation's industries' average level. Electric power industry's healthy circulation of assets and capital has not formed, the modulus of investment profit is dropping, and the unit investment of grid is increasing.

1.3.4 Loose Connection between Electric Power Planning Process and Electric Power Market Supervision

Electric market is the where and how to collocate resources; electric power planning is to plan the collocation. The reason why the two are not connected was because during the process of reforming, corresponding policies were not made or executed well, e.g. the pricing scheme, the allowance for renewable energy and how environmental aspects to be converted into money.

1.4 The Electric Power Market Reform Changed Electric Power Planning Profoundly

Electric power market reform changed some external conditions for electric power planning:

1. The separation of plant and grid has formed more profit main bodies, and at the same time dissevered the integrity electric power's industrial information. Consolidated power planning model formed by incorporated power plants, grid and consumers can no longer fits the current market structure, separated planning for plants and grids may cause the disconnection between each other, and blind spots for planning.
2. The separation of plant and grid changed the main body of planning, power supply planning is conducted by power companies which do not understand the market directly, while grid planning is carried out without knowing the supply.
3. Electric power projects are standardized, the government decides the collocation of resources, both planning and projects are just the tool of the government, which has nothing to do with power enterprises.
4. Enterprises' plans are made by themselves, approved plans of electric power corporations can become the basis for nation's planning, while enterprises in other industries do not enjoy such favorable police. This is against the soul of

market economy—fair competition.

1.5 Proposal of Scientific Electric Power Planning

Scientific electric power planning is just proposed under the above mentioned background, which tries to form a scientific planning method and system that adaptable for electric power market reform, reflects multiple social targets and least total social cost.

The basic attributes of scientific electric power planning are:

1. Scientific electric power planning is an integrative concept that is scientific, logical, complete, economic, durative and effective.
2. The essential thought of scientific electric power planning is to pursue the least total social cost, which requires planning to consider capital cost, operation cost, environment cost and social cost.
3. Scientific electric power planning considers the efficiency management from the demand side, introduces Efficient Power Plant (EPP) and adds it into the combination of power supply so as to achieve a lower production cost.
4. Scientific electric power planning considers environment cost, educes the best power supply development combination by comparing the costs of waste discharges and analyzes the social cost vs. profit of the management on these discharges.
5. Scientific electric power planning unites tightly with government's industrial lead, adjusts the admittance police of electric power market and will prevent unqualified enterprises or projects from entering the market. Electric power planning will reflect what to and not to support.
6. Scientific electric power planning considers other social targets, e.g. the diversity of resources, low price risk, energy saving, universal service, system safety and etc.

2. Basic Mentality and Principle of Scientific Electric Power Planning

2.1 Principles of Scientific Electric Power Planning

1. Set up and complete the IRP planning system

After the former Ministry of Electric Power or National Electric Power Company, which used to push forward IRP planning method, was canceled, national economic macro adjustment department became the main body to push it forward. By comparing the investment to energy saving projects or to new power plants, the advantages and disadvantages between developing renewable energy and regular energy will be shown, and IRP will be brought into electric power planning in all levels.

2. To promote the development of new technology

Scientific electric power planning should reflect new achievements made during the technological development of electric power and consider the impact of scientific progress on electric power industry. In 21^{st} century, electric power planning need to put energy saving in the first place, and make energy saving plans and renewable energy development target in the important position. The 10^{th} 5-year plan remarks “to equally support source development and energy saving, yet put energy saving the first place”, while the 11^{th} 5-year plan refined it into “to insist energy saving the first position”. This is a big transformation of economic guidelines, and scientific electric power planning needs to not only fulfill it but also promote the idea.

3. Bringing DSM into scientific electric power planning

Electric power demand side management is not only the management and service for consumers, it can also be another kind of source, which can be reflected in the following ways: the first is EPP; the second is to reduce the total social specific consumption then further reduce demand by decreasing the specific consumption intensity in many ways; the third is to adjust consumers’ demand by flexible market exchange, so as to optimize the demand curve and power generation ability, then lower the supply and save energy.

4. Adjust power supply structure

Make consumption reducing and energy saving the core concept, force small units quit the market by using market admittance/exit policy, and require new market players to reach certain technological standards; optimize power supply collocation by making energy saving adjustment; energetically encourage the development of clean power; and increase the electric power exchange among different areas.

5. Develop circulative economy, set up electric power planning environmental impact evaluation model

The central government has made electric power industry the experimental industry for developing circulative economy; scientific electric power planning should reflect such policy and help electric power industry to form a series of optimized industrial chain with zero discharge, low consumption and high output, especially in thermal power plants and see side power supply bases.

2.2 Scientific Electric Power Planning to Reflect the Research on Environmental Protection

To guarantee all power plants meet the standard discharge level, desulfurize smoke gas is the key point. Measures should be seriously taken to control and reduce the emission of sulfur dioxide; all newly installed units should be desulfurized. By the end of 2010, the total capacity of desulfurized units in the country will be 320 MW, the efficiency of dust removal will be 99%. New units will use low NOx burning technology, popularize mature water saving and waste water recycle technology. Water consumption of new power plants will be limited below 0.7m /s·Gw, areas lack of water sources will use air cooling technology and the water consumption will not exceed 0.1m /s·Gw, see side power plants will use seawater desalination technology.

2.3 To Utilize the Research Achievement on Electric Power Planning

1. Power transmission investment and expanding plan in electric power market environment

There are two types of transmission expansion in the future. One kind is the long distant transmission from power supply base, where the transmission expansion and power supply development are carried out at the same time, and is relatively certain; the other kind is the decrease of reserve may affect the efficiency of market operation. The possible scales of investment on transmission are as follows:

--public investment (state investment), can be funded by public financial fund or public debt.

--restrained private investment.

--commercial transmission investment, a complementarity for restrained private investment.

2. How electric power planning considers the harmony and balance between power generation and transmission

In electric power market, the different profit needs between power suppliers and power transmitters causes the different requirement from planning and judging standard, which may cause the disjoint of planning or even construction, then further cause the waste of social sources. Therefore the consideration for both power generation and power transmission results in taking the least transmission ullage and least generation cost as the restrains, set up the optimized model then pursue the balance between power networking, generation and transmission.

3. Flexible grid planning

Flexible grid planning is also called soft grid planning, which means to consider all kinds of uncertain elements while planning, and make it to be applicable for the possible changes in the future, and then realize the optimization of the plan. It can be categorized into two types. The first is multiple scenario analysis, the second is mathematics modeling based on uncertain information. Our project utilized the first type.

3. The Multiple Scenario Analysis on the Growth Characteristics of China’s Electric Power

Electric power growth always follows certain rules; to conduct multiple scenario analysis on it can reflect such rules from different aspects. Similar to economic growth, electric power growth is affected by many factors and can not be reflected by one single normative expression. When samples are enough, the reliability of the result grows higher, and can be used for the forecast in the future.

3.1 Electric Power Flexibility

There is electric power consumption flexibility vs. GDP (and the 1st, 2nd and 3rd industries), fixed assets and consumption. We collected and calculated data of 15 years from 1990 to 2005, and listed these flexibilities.

From the chart we can see that the distribution of electric power flexibility between each year was rather disordered. There is a big circle of 18 years from 1990 to 2007, where 1999 is the dividing line. Before that most of the electric power flexibility on GDP is below 1, which reflects the economic structure in that time. From 2000 the flexibility exceeds 1, and some goes beyond 1.5, that is because of the over power consumption of heavy industries such as black metallurgy, colored metallurgy, chemical material, nonmetal products exceeds the average power consumption, and causes the growth of electric power exceeds the growth of GDP. It is foreseeable that such trend will not end; electric power flexibility may drop due to energy saving measures but would not go under 1. This is the normality for China's social electric power development.

Chart 3-1 Electric power flexibility on GDP, investment and consumption

	90	**91**	**92**	**93**	**94**	**95**	**96**	**97**
On GDP	1.66	1.01	0.78	0.74	0.82	0.86	0.74	0.5
On 1st industry		3.3	1.7	0.6	2.1	1.6	1.35	1.86
On 2nd industry		0.58	0.49	0.48	0.47	0.6	0.496	0.27
On 3rd industry		1.61	1.24	1.27	1.55	1.8	1.07	0.87
On investment growth	2.63	0.39	0.25	0.162	0.338	0.518	0.48	0.5
On investment rate	0.261	0.362	0.377	0.27	0.291	0.275	0.221	0.14
On consumption	2.52	0.695	0.673	0.335	0.338	0.354	0.404	0.404

	98	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**
On GDP	0.36	0.92	1.35	1.05	1.53	1.5	1.31	1.31	1.31
On 1st industry		1.88	0.73	2.23	1.25	0.36	0.2	1.22	
On 2nd industry	0.113	0.81	1.8	1.02	1.256	1.31	1.49	1.235	
On 3rd industry	1.01	0.83	1.46	1.01	1.21	1.56	1.52	1.10	
On investment growth	0.2	1.28	1.10	0.608	0.686	0.552	0.57	0.528	
On investment rate	0.083	0.197	0.34	0.256	0.32	0.374	0.344	0.279	
On consumption	0.411	0.964	1.17	0.86	0.983	1.68	1.14	1.05	

Electric power flexibility on investment growth, in spit of some unreasonable data from certain years, seems stable. The average value from 1991 to 2005 is 0.548, and that from 2001 to 2005 is 0.6, which can be used as the benchmark for near & middle term electric power demand forecast.

The electric power flexibility on investment rate is between 0.26 and 0.27 in 90's of last century, around 0.35 in most of the year after 2000, and between 0.26 and 0.28 in certain years. Generally speaking, high investment rate promotes the development of electric power industry, which is a character in Chinese economy in the long run. Macro adjustment targets fixed asset investment to be 40%, while the fact that this rate remains in a higher position during the national economical process won't change by men's intention. Take 0.3 as the flexibility on investment rate is feasible in near &

middle term.

Electric power flexibility on consumption is positively correlated. From 1991 to 1998 the average flexibility is 0.443, and rises to 1.12 from 1999 to 2005 with some unreasonable elements eliminated. The average flexibility is 0.824 from 1990 to 2005. In recent years, the rising of the flexibility is not because of the sales of consumable increased, but because of the high speed increase of electric power consumption of upriver industries. At the moment such trend is still continuing and 1 can be taken as the flexibility for near and middle term electric power demand forecast.

The electric consumption flexibility of the 1st industry is discrete distributed through the years and is of big difference from one and the other. The average value is 1.36 in recent 15 years, and 1.77 in recent 5 years. In spit of statistic error, the value is 1.01 in all 5 years.

There is some up and down of the electric power consumption of the 2nd industry, except the lower value in 1997 and 1998; data of other years are regular. The electric power consumption of the 2nd industry during the 8th and 9th 5-year plan vibrates around 0.5, and increases sharply during the 11th 5-year plan, which is related to the structure of heavy industry. The value drops a bit from 2005, considering energy saving measures, it can come back around 1 or even lower in near & middle term forecast.

The change on the electric power consumption of the 3rd industry is pretty tiny, with an average level of 1.2, that between 2000 and 2005 is 1.14, and 1.1-1.2 will be taken for near & middle term forecast.

3.2 Electric Power Specific Consumption

Electric power specific consumption means the electric consumption of the unit product of one single industry; it reflects the structure, technological and management level of the industry. The chart below shows the detail.

Chart 3-2

	90	91	92	93	94	95	96
GDP specific consumption	3303	3307	3222	3123	3058	3018	2950
1 in 2001 as the benchmark	1.19	1.19	1.16	1.13	1.1	1.09	1.07
Specific consumption of the 1st industry	657					678	745
Benchmark	0.9					0.93	1.02
Specific consumption of the 2nd industry	6309					4351	4114
Benchmark	1.77					1.22	1.16
Specific consumption of the 3rd industry	800					980	999
Benchmark	0.75					0.92	0.94
Specific consumption of industry	7026					4900	4618
Benchmark	1.78					1.24	1.17
Specific consumption of agriculture	542					5563	538.5
Benchmark	1.12					1.15	1.12

97	98	99	00	01	02	03	04	05
2831	2699	2684	2768	2813	2907	3075	3218	3122
1.02	0.98	0.97	1.00	1.02	1.05	1.11	1.16	1.13
768	719	736	732	765	765	754	730	809
1.05	0.98	1.01	1.00	1.05	1.05	1.03	1.00	1.11
3823	3556	3506	3561	3570	3655	3784	3970	3977
1.07	1.8	0.98	1.00	1.00	1.03	1.06	1.11	1.12
1001	1005	1005	1062	1087	1123	1196	1252	1206
0.94	0.95	0.95	1.0	1.02	1.06	1.13	1.18	1.14
4268	3962	3894	3942	3940	4028	4166	4359	4302
1.08	1.01	0.99	1.00	1.00	1.03	1.06	1.11	1.09
533.1	491.8	489.8	481.8	495	482.4	461.6	450.1	436
1.11	1.02	1.02	1.00	1.03	1.00	0.96	0.93	0.90

Chart 3-3

	93	94	95	96	97	98
Steel kwh/T	961.6	954.8	889.7	899.5	847.8	810.2
Colored metal kwh/10kT						
Mining kwh/T	30.1	29.05	27.94	28.24	28.35	38.14
Construction material kwh/eu	97.3	95.03	90.61	92.45	87.07	86.42
Fabric kwh/10kT	3436	3182	2813	2855	2838	2372
Cloth kwh/10k m	1.458	1.463	1.231	1.582	1.407	1.420
Paper kwh/T	743	710	610.6	685.4	638.5	807.5
Chemical material kwh/eu	2516	2296	2205	2196	2083	1925

99	00	01	02	03	04	05
769.6	795.6	724.4	687.2	680.6	645.2	641.8
	7965	8376	8448	8888	8797	8996
28.19	28.19	27.24	24.24	24.07	22.67	23.63
88.33	94.05	91.08	91.51	90.51	90.43	99.1
2233	2262	1985	1917	1757	1325	1438
1.491	1.563	1.662	1.743	1.911	1.629	1.92
909.2	933.6	662.7	594.8	644	663.7	752
1881	2014	2002	1962	2073	1975	2180

Remark: representative product for construction material are 1 ton of cement and 1 standard box of flat glass, for steel is steel material, for fabric is cloth, for colored metal is 10 kinds of colored metal, for chemical material are vitriol and fertilizer. The electric power consumption of the above mentioned 8 categories occupies 52% of that of total industry electric power consumption.

We educe the conclusion after analysis:

3000kWh/100 million Yuan in 1990 can be taken as the benchmark for GDP electric power specific consumption in near & middle term forecast, where the electric power specific consumption of the 2nd industry can be 3800kWh/100 million Yuan, and 1200kWh/100 million Yuan for the 3rd industry.

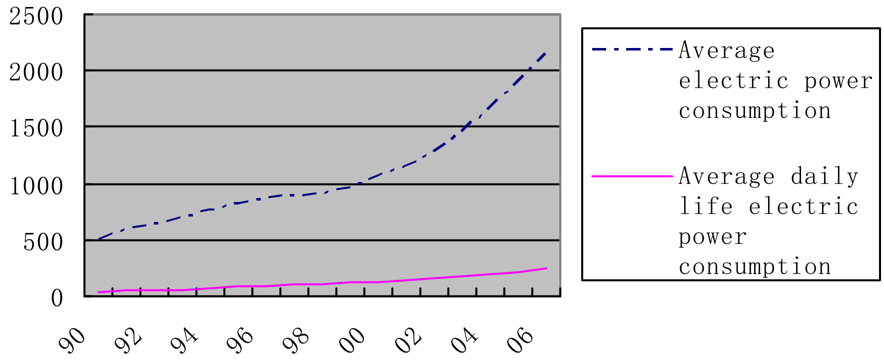
3.3 Average Electric Consumption Kwh/Person

The average electric consumption per head has been increasing.

Chart 3-4

Year	90	91	92	93	94	95	96	97
Average electric power consumption (Kwh/head)	495	578	636	692	754	814	863	893
Average daily life electric power consumption (Kwh/head)	40.3	46	54	61.5	73	82.9	92.6	101.4

98	99	00	01	02	03	04	05	06
909	961	1062	1150	1275	1462	1674	1897	2147
111．2	116.7	132	144	155．8	173	189	216	246



From the chart we can see, the average electric power consumption per person increases smoothly from 1990 to 2000, and accelerated after 2000, which reflects the progress of industrialization. The 2000-4000kWh/head level may remain its increasing trend.

In 2005, electric power occupies 42.66% of total energy (39.44% excluding heating) and the ratio may remain increasing, by the end of the 11th 5-year plan, electric power may occupies 42% of total primary energy. The ratio between energy consumption and electric power consumption can simply be concluded to change from 1:0.4 to 1:0.42 on gross amount.

Data show that when energy consumption decreases by 20%, electric power consumption drops by 7%, considering the above information, when energy consumption decreases by 20%, the electric power consumption in China should decline 7-8.4%, where the energy consumption within electric power industry will count 9% of the total 20% decrease.

4. Forecast on Middle & Long Term Electric Power Demand in

China

4.1 The Economic Development Benchmark Scenario in China

Two plans are made:

Chart 4-1

		2005	2010	2015	2020
Plan I	GDP	183868	271415	389651	541417
	1st industry	22800	28498	33120	34650
	2nd industry	86969	142493	199501	270167
	3rd industry	740901	100423	157029	236058
Plan II	GDP	183868	290776	433212	613302
	1st industry	22800	31113	38555	43544
	2nd industry	86969	157310	232634	321983
	3rd industry	74099	102353	163754	247774

Remark: price is calculated by the level of 2005

Chart 4-2

		2005	2010	2015	2020
Plan I	Investment	88774	101238	139495	188954
	Retail	67177	134893	199891	282619
Plan II	Investment	88774	136664	190613	245320
	Retail	67177	109942	180083	286523

4.2 Forecast Result on Electric Power Demand

Chart 4-3

		A	B	C	D	E	F	G	H	I
Plan 1	2010	37971	36559	43868	40992	40457	42515	44863	36070	33642
	2015	52637	44069	69755	63588	62606	68262	65827	47864	42925
	2020	69712	55116	11354	95852	93921	108901	89386	62296	64065
Plan 2	2010	40936	39167	46062	42116	41991	42515	47833	39482	37006
	2015	58687	48996	76920	66902	67182	69901	67054	55085	47217
	2020	78982	62434	119058	103287	103842	114016	112701	73111	70472

In the chart: A-flexibility index, B-GDP specific consumption, C-electric power consumption flexibility on investment increase, D-electric power consumption flexibility in investment year, E-electric power consumption flexibility on consumption increase, F-electric power consumption flexibility in consumption year, G-electric power consumption flexibility on the 1st, 2nd and 3rd industry, H- electric power specific consumption on the 1st, 2nd and 3rd industry, I-average electric power consumption per person.

Average:

Plan I	2010	39660
	2015	57503
	2020	83621
Plan II	2010	41900
	2015	62044
	2020	93100

5. Using Reliability Principle to Choose Power Supply Reserve Rate

Random faults can not be avoided in electric power facilities, in order to guarantee the constant power supply for consumers, power system must have a certain spare volume; the rate spare volume is called percentage reserve.

$$\text{persentage reserve} = \frac{\text{installed generation capacity} - \text{maximum load}}{\text{maximum load}}$$

Or it can be expressed as:

Installed capacity=maximum load (1+percentage reserve)

Therefore, choosing percentage reserve greatly impacts installed capacity. China's Electric Power System Safety & Stability Guide (DL755-2001) regulated that the system reserve should not lower than 20% of system's maximum generation load. The method to fix the percentage reserve using regulations or guidebooks is called certain method.

However the operation of electric power system impacts the percentage reserve in many aspects, e.g. power supply structure, operational reliability for generation units, examine and repair, load characters and etc. So when installed capacity gets bigger and bigger, units become more and larger, using certain method may seem rough. Using probability analysis method to quantitatively analyze the reliability of power generation units, set reliability data then choose reasonable reserve and generation unit capacity becomes one of the core contents of scientific electric power planning.

Electric power planning considers the large picture, the electric power reliability center has calculated the reliability data in 1997 and 2000 and educed a series of rules of how to using reliability principle.

1. The weighted average of Equivalent Forced Outrage Rate (EFOR) in each grid

Area	1997（1）	1997（2）	2000（1）	2000（2）
Northeast	0.0196	0.0228	0.0388	0.0373
North	0.0306	0.0349	0.0462	0.0808
Northwest	0.0467	0.0524	0.0549	0.0733
East	0.0266	0.0344	0.0411	0.0526

Central	0.0230	0.0274	0.0497	0.0505
Shandong	0.0182	0.0226	0.0456	0.0427
Fujian	0.0123	0.0133	0.0195	0.0233

Remark: (1) 3 kinds of EFOR; (2) 5 kinds of EFOR

2. Reliability result of each grid in 1997

Area	Weighted Average EFOR%	Percentage Reserve
Northeast	2.28	25.62
North	3.95	31.91
Northwest	5.24	45.14
East	3.44	17.63
Central	2.74	38.52
Shandong	2.26	23.18
Fujian	1.33	32.15
Sichuan & Chongqing	1.88	22.52

3. Reliability result of each grid in 2000

Area	Weighted Average EFOR%	Percentage Reserve
Northeast	3.73	32.78
North	8.08	29.43
Northwest	7.33	30.18
East	5.26	21.43
Central	5.05	45.40
Shandong	4.27	22.46
Fujian	2.33	42.48
Sichuan & Chongqing	5.17	35.69

4. The relativity between reliability level and percentage reserve

EFOR impacts reserve greatly and differently in different gird. In order to analyze to relationship between LOLE, EFOR and percentage reserve rate, a curve chart is listed below:

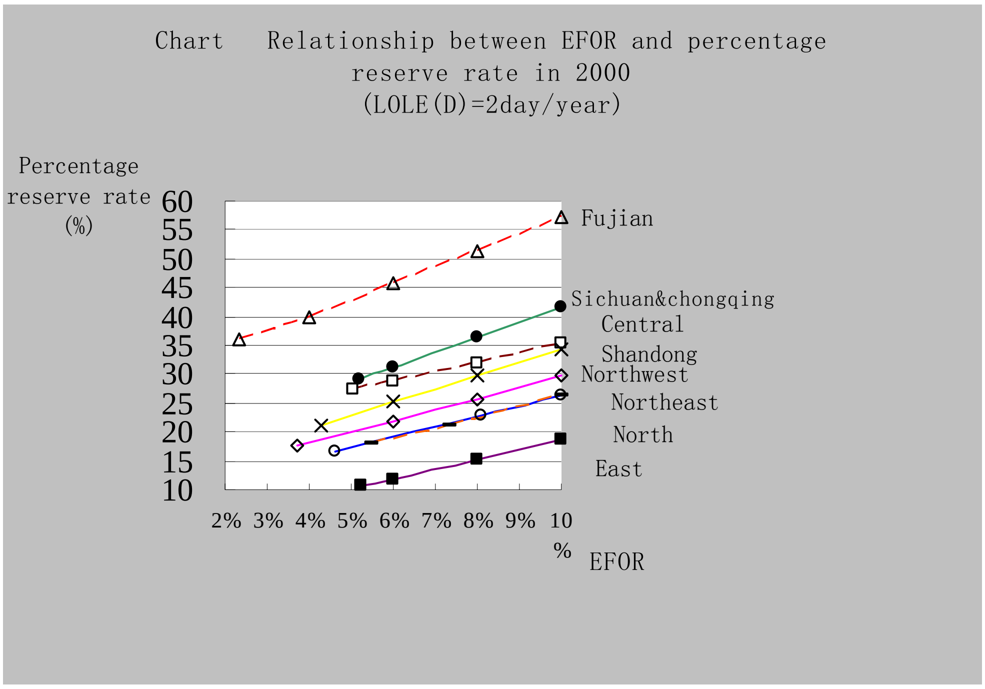


Chart Relationship between EFOR and percentage reserve rate in 2000 (LOLE(D)=2day/year)

The chart shows that the impact of EFOR on percentage reserve is linearly related and with similar gradient, which reflects the relativity between EFOR and percentage rate in the future. The chart also shows that once the weighted average EFOR increases by 1%, the reserve in northeast, north, central and northwest China increases by 1.7-1.9%; and the reserve in Shandong, Fujian, Sichuan and Chongqing increases by 2.3-3.0% (grid scale, thermal and hydro power plant all impact percentage reserve).

When take weighted average EFOR as 4-8%, the reserve in east China is below 15%, that in north, northwest and northeast China is between 15-25%, that in Shandong is 20-30%, 25-35% in central China, Sichuan & Chongqing, and 40-50% in Fujian.

6. Real Diagnosis Analysis of Reliability during the 11th 5-year Plan

In 2005, thermal power, hydro power, unclear energy occupies 76.95%, 20.60% and 2.45% of total generated power, 100MW or above thermal power, 40MW or above hydro power and unclear generation unit that taken into reliability calculation was 1642.5GWh, where thermal power counted 1371.7GWh, 83.51% of the total; hydro power counted 217.7GWh, 13.26% of the total, nuclear energy counted 53.1GWh, 3.23% of the total. In order to show the different impact of EFOR in 2000 and 2005 by using different units, the chart below lists out the EFOR of thermal power 100MW and above, hydro power 40MW and above, and unclear typical unit

Chart 6-1 2000～2005 typical unit EFOR

Unit Capacity (MW) \ Year unit EFOR		2000	2001	2002	2003	2004	2005	Average
Thermal power	100	0.78	1.17	0.79	0.75			0.91
	200	1.61	1.57	1.58	146	1.78	1.34	1.56
	300	1.77	1.27	1.09	1.49	1.17	0.81	1.27
	350	1.01	1.23	1.05	1.42	0.43	0.47	1.10
	500	3.10	2.48	1.47	0.52	0.46	0.51	1.42
	600	3.23	2.21	2.04	1.13	1.10	1.07	1.80
	700		5.20	0.42	1.89	1.08	2.13	2.14
	800		3.57	0.97	3.47	0.35	0.62	1.80
Hydro power	axial-flow	0.04	0.06	0.22	0.20	0.02	0.11	0.11
	Francis Turbines	0.30	0.46	0.13	0.12	0.43	0.12	0.26
	storage	16.64	10.83	2.01	0.86	0.49	0.66	5.25
	total	1.36	0.97	0.26	0.18	0.36	0.14	0.55
Unclear power		1.20	0.68	7.08	3.17	3.33	0.76	2.70

We can see from the above that the EFOR value of different unit can be different. In thermal units, the EFOR is increasing as the capacity grows, and the total EFOR value of units with same capacity is generally decreasing, which is largely related to technological improvement and changes in unit components. In hydro units, the EFOR of pumped storage unit is relatively large, while generally speaking the capacity of hydro power units is much smaller than that of thermal power units. There are some ups and downs of unclear energy EFOR, while the general trend is decrease.

In order to calculate the EFOR value of each area, the chart below list out the unit component in different areas in 2005.

Chart 6-2 Unit component in different areas in 2005

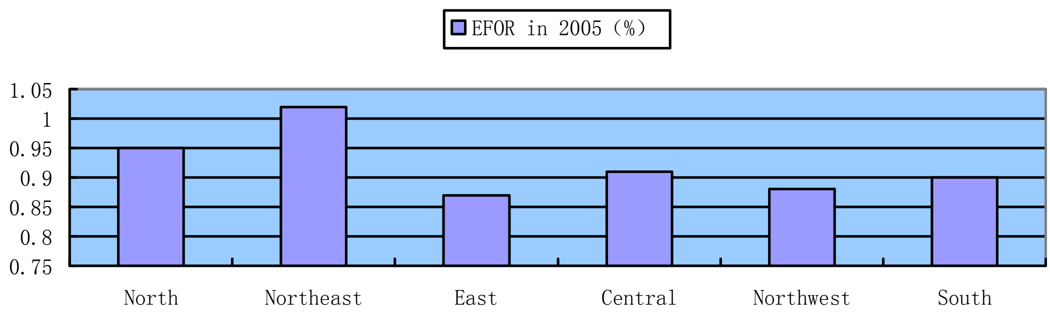
Unit capacity (MW)	north	northeast	east	central	northwest	south
900			2			
800		2				
660	2					
600	18	2	24	2	2	7
350				2		
300	107	23	90	64	32	54

210				2		
200	75	49	20	34	10	22
120						1
100	112	44	107	68	33	56
Total unit	314	120	243	172	77	140

In order to reflect the impact of different power supply structure and different units EFOR on the calculation of reliability, the chart below listed out the weighted average of EFOR in different grid from 2000 to 2005

Chart 6-3 Weighted average EFOR in different grid from 2000 to 2005

area / EFOR（%）	north	northeast	east	central	northwest	south
2000	1.50	1.11	1.48	1.34	1.36	1.41
2001	1.47	1.41	1.36	1.30	1.29	1.19
2002	1.15	1.19	1.09	1.07	1.05	1.09
2003	1.20	1.23	1.14	1.18	1.16	1.17
2004	1.16	1.25	1.03	1.11	1.07	1.10
2005	0.95	1.02	0.87	0.91	0.88	0.90
Average value in each year	1.24	1.20	1.16	1.15	1.14	1.14



From the chart we can tell the EFOR in 2005 is obviously lower than that in 2000, and the EFOR in different areas are all dropping, which means there are spaces for further decrease on reserve in these areas.

According to the theory that once weighted EFOR increases by 1%, the reserve in corresponding grid increases by 1.7-1.9%, taking standard LOLE (D) as 1d/a～2d/a, the corresponding reserve for each grid is:

Area	Northeast	North	Northwest	Central	East	South
EFOR(%)	1.02	0.95	0.88	0.91	0.87	0.90
reserve(%)	17.58~25.09	20.31~23.61	20.48~22.81	26.99~31.54	10.56~14.40	21.28~29.37