Research on Power Supply Voltage Regulation of Large Users Adapting to Doing Business Promotion in Shanghai

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***Abstract*—This paper focuses on the analysis of voltage regulation of large users in Shanghai under the new circumstance of Doing Business. Through the comparison of current regulation rules of power supply voltage for large users in other foreign and domestic cities, the primary optimal strategy to promote Doing Business has been raised. Focused on the users with the capacity from 8MVA to 40MVA, the sensitivity analysis with the adjustment of capacity limit has been fully studied. Taking the limit capacity for 10kV users as a typical case, the influence of increasing the upper limit have been considered from the utility, users and the whole society perspectives. Along with the technical-economical evaluation, the paper finally proposes a practical optimal strategy of users voltage regulation, to advance a mutually beneficial and win-win situation of entire society.**

Keywords:
Doing Business, Voltage levels of large users, Promotion strategies, Economical efficiency

I. Introduction

As the next global city, power supply development should be coincident with the fast development of the city. As we can see, the selection of power supply voltage for large users is directly related to the benefit of utility and users. The previous research mostly focused on the reasonable configuration of the voltage level on the utility side and less consideration of the benefit on users and whole society. With the new requirements of Doing Business in Shanghai, the initial investment of users and the time of getting an electricity connection improve the business environment significantly. Based on the current states of power supply voltage for large users, it comes to a conclusion that the voltage of 35kV plays a crucial role in power supply of large users. Then we made a comparison of current regulation rules in advanced cities such as Tokyo, London and other domestic cities. With a consideration of detail requirement such as procedures, time and cost to get connected to the electrical grid, we take the users with the capacity from 8MVA to 40MVA as our target. For the aspects of utility, users and the whole society, technical and economic analysis should be taken to insure the feasibility of regulation adjustment. Along with a deep study on investment, resource cost and time to get connected to the grid, we will propose some specific strategies for promoting the regulation rules.

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II. Current regulation rules of power supply voltage for large users

110kV network is taken as the main direction of high voltage network in Shanghai, but the grid also develops 35kV network carefully if really necessary. As the main voltage for large users with the capacity from 8MVA to 40MVA, 35kV network takes its advantage.

A. States of large users in Shanghai

35kV network is taken as the main voltage for users with the capacity from 8MVA to 40MVA in Shanghai. But still, some of the users with a larger capacity over 8MVA are provided by the 10kV network especially in Pudong district. We take the 156 user thin the capacity from 8MVA to 40MVA in recent 4 years as the sample, we find that 128 users are provided by 35kV network and 28 users are provided by 10kV network. For the 10kV users, their capacities are basically below 16MVA. As far as the different power supply areas are concerned, most of the large users in A+ and A areas are offices, colleges, hospitals, and scientific research institutions. As for B areas, large industrial users are mainly concentrated. On the capacity side, 92% users are mainly concentrated within 10MVA and 20MV, which are provided by dual supply line. The number of large users is estimated to over 60 per year.

B. Current regulation rules at home and abroad

In this section, current regulation rules in advanced cities such as Tokyo, London and other domestic cities has been collected and analyzed.

The power supply voltage level of Tokyo is determined according to the maximum load of the user rather than the maximum capacity. The maximum load refers to the number defined by the contract between user and TEPCO, as shown in Table 1.

TABLE 1 REGULATION RULES OF POWER SUPPLY VOLTAGE IN TEPCO

Voltage level	Maximum Load
154kV	>50MW
66kV	10MW～50MW
22kV	2MW～10MW
6.6kV	50kW～2000kW

The medium voltage distribution network in Tokyo has two voltage levels. The and. The maximum load of 6.6kV users is controlled under 2MW and 10MW for the 22kV users. The load limit is basically matched to the rated capacity of distribution line with a little margin.

As for London, the regulation rules are determined by the capacity of users in the standard of EDS 08-0141 and EDS 08-1050, as shown in Table 2.

TABLE 2 REGULATION RULES OF POWER SUPPLY VOLTAGE IN LONDON

Voltage level	Maximum Load
33kV	>5MVA
11kV	1～7.6MVA
6.6kV	1～4.5MVA
Low voltage	<1MVA

Also, London has two medium voltage level. The maximum load of 6.6kV users is limited under 4.5MVA and 7.6MVA for the 11kV users, which matches to the rated capacity of distribution line as well.

Many domestic provinces and cities,such as Beijing, Tianjin, Zhejiang, Jiangsu, control the access capacity of 35kV and 10kV users in the same way. Under the condition of 35kV distribution network, the upper limit of 10kV user capacity is controlled from 7MVA to 10MVA. If there is no 35kV level, users are usually supplied by 10kV network with more than two lines. The upper limit of these 10kV users is controlled from 14MVA to 20MVA.

We can easily find the difference between Shanghai and other cites abroad, that is, the upper capacity limit of 10kV user is larger than the rated capacity of a single line. If there is no 35kV level, users are usually supplied by 10kV network up to the capacity limit of 30MVA, which is higher than many domestic cities.When the user capacity is above 40MVA, 110kV level and above are generally used.

C. New demands for Doing Business

The business environment is an important soft power of a country or region as well as the core competitiveness. Doing Business is a annual report from the World Bank focus on promoting regulatory reform to create more opportunities for the economy to prosper. Getting-electricity is one of the 11 indicator sets which measure aspects of business regulation.

China's Getting-electricity score depends mainly on the city of Shanghai and Beijing. As the next global city, Shanghai must make some breakthroughs in optimizing the business environment. To promote the score, time and cost of getting electricity are much more concerned. Reasonable user power supply voltage adjustment will effectively enhance the indicator set. In this paper, we wish to promoting the voltage regulation rules by raising the upper limit of large users in 10kV and the economic efficiency of utility, users and entire society will be raised evidently.

III. RESEARCH PLANS FOR VOLTAGE REGULATION OF LARGE USERS

A. Main research ideas

If the current main 35kV users (8MVA~30MVA) switch to 110kV level, a large amount of 110kV outgoing resources in 220kV substations should be occupied.if these 110kV users choose to be supplied by 110kV substations, the channel resource of these substations would face higher pressure. On the aspect of investment economy, increasing the voltage level of power supply to users generally means to reduce the construction cost and electricity price. But consider the triple occupation of channel resource by 110kV cable and other investment on 110kV switch station and user station, the total investment will increase by 1 time for users who choose accessing to 110kV grid. For users, although the electricity charge is reduced by 2.2%, but it is not enough to make up for the initial construction investment. For the utility, the income will decrease for the difference price between 110kV and 35kV grid.

If the current main 35kV users switch to 10kV level, utilities need to build more 110kV substations and much more cables to meet the load demand. That means the investment by utilities increase efficiently. For users, although the average price is higher and the electricity charge increases, the initial investment is reduced by more than 1 times, and the time of getting electricity is shortened.

Thus, we can see that the appropriate adjustment of the user capacity to access the 10kV voltage level will effectively reduce the user’s initial investment and shorten the time of getting electricity, which is the main measure to improve the getting electricity index and improve the business environment. On the other hand, the excessive raising of accessing requirements will greatly increase the construction cost for power supply utility. In order to enhance the overall social benefits and improve the environment of Doing Business, a research plan aims to adjusts the upper limit of 10kV user capacity appropriately has been proposed as follows.

B. *Proposal of Adjustment Plans*

According to the current regulation rules of supply voltage the upper limit of installation capacity for 10kV users is 8MVA, and users with a capacity of 40MVA and above generally take 110kV as supply voltage level. It is determined that the limit increase range of 10kV is from 8MVA to 40MVA. That means users need to be supplied with multi-loop 10kV lines.

According to the references on user supply voltage at home and abroad, 10MVA, the upper limit capacity of 10kV customers in both industry standard and business standard of State Grid, is considered as a first proposal. Furthermore, some certain rules are pointed in the Annex E of the "Shanghai Power Grid Planning and Design Technical Guidelines (Trial)". Cable line is laid in 3 × 7-hole power pipe; the rated current and capacity of the 10kV line is around 360A and 6300kVA respectively. The combined capacity of multi-loop 10kV lines is used as other plans, as shown in Table 3.

TABLE 3 ADJUSTMENT PLANS ON CAPACITY OF 10KV USERS

plans	Upgrading range at 10kV（MVA）	Number of lines at 10kV
A	8-10	2
B	8-12.6	2
C	8-18.9	2-3
D	8-25.2	2-4
E	8-31.5	2-5
F	8-37.8	2-6
G	8-40	2-7

IV. PROMOTION STRATEGY OF LARGE USERS ADAPTING TO DOING BUSINESS PROMOTION

A. *Primary strategies*

According to the constitution principle of getting electricity index, the basic optimization strategy has been raised as follows. For the distribution network of Shanghai, we should keep building the world-class network with the rapid industrial structure adjustment and the accelerating growth of user demand. The primary strategy aims to achieve a better social benefit by optimizing the time and cost of getting electricity for users.

This paper takes into account the combined impact on utility, users and society when 35kV users turn to 10kV users. Under the feasibility of 10kV multi-loop supply, the main aspects of utility such as economic efficiency, land resources, capacity, influence on network structure and power supply reliability are fully analyzed. For the users and society, quantitative analysis is carried out in the aspects of economical efficiency, land resources, channel resources and time of getting electricity.

B. *Impact on utility*

For the utility, we focus on economical efficiency, land resources, capacity resources, network structure and power supply reliability. They are used as the constraint conditions for capacity limit increasing of 10kV users. We take economical efficiency and network structure analysis as the typical case in detail.

Economical Efficiency

If the upper limit of 10kV users installation capacity is increased, the investment cost and income changes of utilities include the following two parts.The increasing cost contains the investment on 110(35)kV substations, cables,channels and operation cost in the LCC loop. The increasing income includes the capacity charge for multi-loop supply and the difference of electricity price between 35kV users and 10kV users(0.025 yuan/kWh). the detail comparison is shown in Table 4.

TABLE 4 ECONOMICAL EFFICIENCY ON UTILITY

Upgrading range at 10kV（MVA）	Initial investment(RMB)		Within the LCC loop(RMB)	
	Increasing cost per user（million）	Annual increasing cost（million）	Economic efficiency of utility investment per user（million）	Total economic efficiency in a LCC loop（million）
8-10	9.82	108.01	-4.78	-52.60
8-12.6	11.37	306.98	-5.54	-149.49
8-18.9	12.63	492.76	-6.03	-235.19
8-25.2	14.53	726.29	-6.80	-339.84
8-31.5	14.78	753.90	-6.90	-351.90
8-37.8	15.56	840.49	-7.21	-389.59
8-40	19.48	1168.83	-8.90	-533.88

We can see in the table that the initial investment would increase, and the annual investment would increase by approximately 1 to 11.7 billion.The increasing electricity charge is not enough to make up for the equipment investment and operating cost of new substations and lines. The investment by utility would result in losses during the equipment operation cycle, with amount of about 52 to 533 million. To achieve a long-term balanced budget, the capacity limit of 10kV customers should be about 3.5MVA..

When the capacity limit of 10kV customers increases to 10-25.2MVA, the initial investment and loss grow much faster due to the large number of customers.

Impact on nerwork structure

Currently, 10kV uses are mainly supplied through a transfer of 10kV switch stations, which is similar to 35kV access mode. However, when the capacity limit of 10kV customers increases greatly (above 12.6MVA), the switch station can not afford the other users or stations nearby because of the heavy load of 10kV users. At the same time, the 10kV network structure would be separated apart and the transmission ability will be limited, which means the reliability can be effected badly.

In general, the initial investment of utility will increase efficiently, and then lead to losses in the equipment operation cycle. The demand for channel resources will increase greatly, which will become the main bottleneck in the implementation of power grid construction. The land resource of substation has been greatly reduced which is a good news to users and the society, but the construction period of the substation has been prolonged. Distribution network structure is weakened as well as the power supply reliability declines slightly.

C. Impact on users

Economic Effeciency

After increasing the capacity limit of 10kV users, the initial investment of users would decrease, including the 35kV user substations and the cables 35kV network to 10kV network. Calculation shows that after the 10kV user capacity limit increases, the initial investment of users will drop efficiently, and the average initial investment of each user will drop by about 11 million to 15million. In the equipment operation cycle, users will benefit, and the average cost per user is about 1 million to 6 million.

Land Resources

When the limit increases, the original 35kV users do not need to build 35kV substations, reducing a large area for each user per year. Especially for commercial users who account for about 70% of the range, the reduction of land resource utilization would generate greater economic benefits.

Time of getting electricity

In terms of connecting period, it spends an average176 days for 35kV users, and 97 days for 10kV users to get power. With the increasing limit of 10kV users, the average user saves about 79 days for getting access and greatly helps to improve service quality which is very important to optimize the Doing Business environment. However, on the other hand, the utility needs to build the additional 110kV substations to meet the extra demand for the new 10kV users with a longer time. Therefore, the reduction of connecting time is based on the long construction period of substations.

In general, users are the main beneficial owners.

D. Impact on whole society

For the whole society, quantitative analysis is carried out in the aspects of economical efficiency, land resources, channel resources.

Economic Effeciency

Referring to the technical-economical analysis of utility and user comprehensively, the economic benefit analysis of the total social, after the increasing limit of 10kV customers, can be obtained, as shown in Table 5.

TABLE 5 ECONOMIC EFFICIENCY ON WHOLE SOCIETY

Upgrading range at 10kV（MVA）	Initial investment(RMB)		Within the LCC loop(RMB)	
	Increasing cost per user（million）	Annual increasing cost（million）	Economic efficiency of utility investment per user（million）	Total economic efficiency in a LCC loop（million）
8-10	-1.51	-16.57	0.8	8.80
8-12.6	-0.85	-22.94	-0.17	-4.56
8-18.9	0.13	4.88	-1.52	-59.35
8-25.2	1.72	85.99	-3.71	-185.32
8-31.5	1.93	98.51	-4.47	-227.85
8-37.8	2.57	138.81	-4.88	-263.32
8-40	4.70	281.71	-7.94	-476.36

For the initial investment, when the capacity limit rises up to around 15MVA, the whole society would achieve the balance. If the limit continues to increase, the overall investment would also grow. in view of economic benefits in the equipment operation cycle, when the limit rises up to approximately 11MVA, the overall economic benefits would come to a balance. If the limit continues to increase, the overall economic benefits would suffer losses.

Land Resources

If we centralize the intensive and low capacity 35kV user station to the large capacity of 110kV substation, the land area of the whole social substation will be greatly reduced, and the users are the biggest winner by saving the land resources.

In general, the initial investment of the whole society is balanced when the limit of 10kV user capacity raise to about 15MVA. If the limit continues to increase, the total social investment will increase, the overall of the social line channel resources will grow, the line loss increases obviously, and the whole social benefit decreases.

V. CASE STUDY AND DISCUSSION

We take large users who accessed to the grid since 2013 as a typical case. There are 156 users with a capacity from 8MVA to 40MVA and a total capacity up to 2442MVA. The study presents quantitative impact on economic benefits, power reliability, network structure and channel resources, etc. after user voltage adjustment. The summary of research is shown in table 6.

VI. CONCLUSION

By means of technical-economical comparison of the combined impacts on utility, users and society, a principal conclusion for rational voltage level is obtained.

To sum up, due to the current development of distribution system in each area, from the perspective of optimal social investment, it is suggested that the capacity limit for 10kV customers should be increased within the range of 8MVA to 12.6MVA.It helps to optimize the network structure, and social resources as well. Besides, from the perspective of high reliability demand, the limit reduces to around 12000kVA. Meanwhile, in order not to increase the pressure of original 35kV substations, the limit maintain still at 8000kVA within the supplying region of these substations. As a result, it contributes to an optimal regional grid structure and high energy efficiency.The limit capacity for 10kV users should be increased within the range of 8MVA to 12.6MVA, prompting a coordinated development at different voltage levels in distribution network.

TABLE 6 SUMMARY OF RESEARCH AND ANALYSIS ON THE ADJUSTMENT PLANS ON INCREASING THE UPPER LIMIT CAPACITY OF 10KV USERS

		8MVA-10MVA	8MVA-12.6MVA	8000kVA-40MVA
SAIDI		30% decrease		
Line loss		21% increase		
Time of getting power		Cut 79 day per user		
Distrbution network		Loop for backbone	Radial for several users	Radial for most users in special areas
Economical efficiency	Annual investment	Utility increasing User decreasing Entrie society decreasing	Keep balance	Utility increasing User decreasing Entrie society increasing
	LCC efficiency	Utility increasing User decreasing Entrie society increasing	Balance point 11MVA	Utility decreasing User increasing Entrie society decreasing
Land resource		Municipal land for substation increasing Users land forsubstation decreasing Total land use of society decreasing		

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