RESEARCH ON THE APPLICATION OF MULTIPLE ENERGY STORAGE SYSTEM IN SHANGHAI POWER GRID

Xiaowen DONG
Shanghai Municipal Electric Power Company – China
xiaowen_dong@126.com

Guoqin YU
Shanghai Municipal Electric Power Company – China
yugq@sh.sgcc.com.cn

Yu ZHANG
Shanghai Municipal Electric Power Company – China
zhangy@etc.sh.sgcc.com.cn

Weiguo HE
Shanghai Municipal Electric Power Company – China
hewg@sh.sgcc.com.cn

Xinze JIANG
Shanghai Municipal Electric Power Company – China
jiangxz@etc.sh.sgcc.com.cn

ABSTRACT

By analyzing the influences given by the multiple energy storage system on the power quality, including the conversion efficiency, fault analysis, and general quality, this paper assesses the operation and performance of Shanghai Power Grid, and then the final determination is made for the optimized energy storage solution for the access to the grid.

INTRODUCTION

Shanghai city, the biggest city in China, is under rapid economic growth facing great challenge of energy supply and demand tension. For the Power Grid construction is hindered, parts of areas in Shanghai have met the insufficient power supply. As the difference between the peak and valley is increasingly enlarged, the supply-demand conflict has shifted in recent years here. The issue of lack of source has changed to the power lack in both grid and source. In accordance with the characteristics of Shanghai Power Grid, Shanghai Power Grid introduces the step of energy storage to take the place of the routine power increase-capacity reconstruction, which will optimize the grid by "cutting peak and filling valley" and realizes the smart power distribution.

By analyzing the influences given by the multiple energy storage system on the power quality, including the conversion efficiency, fault analysis, and general quality, this paper assesses the operation and performance of Shanghai Power Grid, and then the final determination is made for the optimized energy storage solution for the access to the grid.

CHARACTERISTICS OF SHANGHAI POWER GRID

The power load in Shanghai has already transformed to type of modern international metropolis which has a fast increase electricity load with big peak valley difference as a typical receiving Power Grid[1].

(1) With the insufficient primary energy and valuable land resources, resources and environment have more obvious restrictions on the development of Power Grid, it is difficult to satisfy with the sustainably-growing power needs if totally relying on the local power construction and it is an essential choice to receive the large-scale foreign incoming electricity. In 2010 in load peak time, the maximum foreign electricity accounts for 38% of the total, however, meantime receiving a large number satisfying with utilization need, the self-control ability will be enormously weakened, bringing forward greater challenge to safety and stability of Power Grid.

(2) Shanghai Power Grid, an oversize city's type, has big peak valley difference with the growing trend year by year. With increase of peak valley difference, the peak-adjusting pressure is big and the average utilization rate of Power Grid equipment is hard to improve. In 2010 the maximum peak valley difference reaches 10098MW, accounting for over 38%. It is estimated that in 2020 the peak valley difference of Shanghai Power Grid will account for nearly 50% in maximum load, while the daily minimum load rate from 2010 to 2020 is between 0.52 to 0.50 and the daily power average load rate drops down to 0.80[2].

(3) The main types of power generation from renewable energy in Shanghai Power Grid are waste incineration, wind power generation and solar power. With the increasing development of renewable energy generation projects, the renewable energy power generation projects under and upcoming construction take on characteristics of large quantity and big volume. Up to the end of 2009, the assembly machine volume of enterprises on the internet through renewable energy built and put into operation in Shanghai reach 400MW. The intermittence, randomicity and wave properties of the renewable energy, especially wind power generation and solar power will have a greater impact on the Power Grid.

(4) Shanghai possesses many high-tech enterprises with high requirement on the safety and reliability of utilization. The times (time) of power cut and power cut loss reduces, and the produced economical benefits and social benefits are obvious.

ENERGY STORAGE SYSTEM APPLICATION IN SHANGHAI POWER GRID

Limited by the routine inertia and operation economical efficiency of generating equipment, the traditional power supply (hydropower, thermoelectricity and nuclear power) has a large scale and continuity; but the randomicity and intermittence of load causes the essential contradiction between these two. Though it can be solved through enhancing power and Power Grid construction & investment, this will cause big reduction of utilization efficiency of generation, transmission and transformation equipment and seriously influence on the utilization efficiency of primary energy and operation economical efficiency of power plant. The large-scale development and utilization of new-type energies (wind power, photovoltaic generation) will aggravate and worsen the contradiction further, so that is desiderate to break through the related key technologies of energy storage, open large-volume and large-scale battery energy storage systems to improve the utilization efficiency of primary energy, power transmission and transformation equipment and reduce the emission of greenhouse gases.

Shanghai Power Grid built Caoxi Energy Conversion Base in 2010 (see figure 1), which has the first electric vehicle charging and discharging station with business operation ability, large-volume city Power Grid energy storage station and centralized control system, which will intensively show the technical results and application prospects. Energy storage station has various types of energy storage subsystems of 400Kw and has built comprehensive management platform（SG-GESS）(see figure 2) and has gradually completed the charging and discharging policies and system integration according to the operation experience. The accessed energy storage system includes: 100kW/200kWh ni-mh battery energy storage system, one set; 10kW/20kWh sap flow battery energy storage system, one set; 100kW/80kWh iron battery energy storage system, one set.

ENERGY STORAGE TEST

Caoxi Energy Conversion Base mainly develops energy storage system test, evaluates technology study, and builds open energy storage system, electrokinetic cell and parallel-in equipment comprehensive test platform at present. They are mainly tests and evaluations in four aspects: (1) monomer battery performance test and evaluation; (2) module battery performance test and evaluation (small-scale group cell system, ordinarily are many monomer batteries series-parallel connection, with BMS concluding PCS, the volume is small than 10kWh ordinarily); (3) power energy storage system test (battery system is ordinarily the module battery large-scale system integration, energy system includes BMS and PCS with the total volume bigger than 100kWh); (4) the test and evaluation of parallel-in equipment’ s PCS in energy storage system. The division of the above volume ranges can be mainly according to the present battery industry status and with the development of technology, the volume range may change.

Caoxi Energy Conversion Base provides with routine operation tests and multiple extreme conditions operation tests according to the different test requirements, among which the extreme conditions operation tests will be restricted to software and hardware as well as technical levels of Base itself needing to be completed from time to time. As a kind of electrical equipment, energy storage system must take electricity performance, safety performance and environment adapbility performance in consideration, but for the current test conditions and test costs, the available energy storage system tests are mainly routine operation ones, and concretely are electricity performance standards, such as electrical energy quality after parallel-in, overall system conversion efficiency, as well as routine noise and insulating properties tests. The Fig 3 is for the valid value of three-phase voltage when the power quality of the energy storage system is analyzed. The Fig 4 is for the harmonic wave group. And the Fig 5 is about the short time flicker.

The specific test items are as follows:

1. Voltage deviation . Equipment work status: energy storage system discharges with the rated power output of 100kW.
2. Frequency deviation . Equipment work status: energy storage system discharges with the rated power output of 100kW.
3. Power factor . Equipment work status: energy storage system discharges with the power outputs of desperately 30kW, 50kW and 100kW.
4. Voltage harmonics. Equipment work status: energy storage system discharges with the rated power output of 100kW.
5. Current harmonics. Equipment work status: energy storage system discharges with the rated power output of 100kW.
6. Voltage imbalance. Equipment work status: energy storage system discharges with the power outputs of desperately 30kW, 50kW and 100kW.
7. System efficiency test. Equipment work status: (1) Energy storage system charges with the power of 30kW, discharges with the power outputs of desperately 30kW, 50kW and 100kW and measures the charging electric energy and discharging electric energy on the condition of equivalent current in direct current status. (2) Energy storage system

charges with the power of 40kW, discharges with the power outputs of desperately 30kW, 50kW and 100kW and measures the charging electric energy and discharging electric energy on the condition of equivalent current in direct current status. (3) Energy storage system charges with the power of 50kW, discharges with the power outputs of desperately 30kW, 50kW and 100kW and measures the charging electric energy and discharging electric energy on the condition of equivalent current in direct current status.

8. Switchover time between charging and discharging. Equipment work status: (1) Control energy storage system to charge with the power of 50kW and changes to the status of discharging with the power of 100Kw. Monitor the switchover time of power in parallel-in position of energy storage system. (2) Control energy storage system to charge with the power of 50kW and changes to the status of discharging with the power of 100Kw. Monitor the switchover time of power in parallel-in position of energy storage system.
9. Insulating resistance test. Equipment work status: energy storage system does not work.
10. Insulating intensity test. Equipment work status: energy storage system does not work.
11. Noise test.

DISCUSSION

Nickel and cadmium batteries has high efficiency and long cycle life, but with increasing times of charging and discharging, the volume will be reduced, charge retention ability still needs to be improved and they are limited to use by EU organization for heavy metal pollution. Lithium ion battery has higher specific energy/specific power, small self-discharging and friendly environment, but for influence of factors for technique and environment temperature difference, system standards can't reach the monomer level always, and its service life is several times smaller even over ten times smaller. The technical difficulty and production maintenance cost of large-volume integration make the batteries hardly be used in scale in power system in a long period of time[3].

Sodium and sulfur and sap flow batteries are considered to be new and efficient large-scale power energy storage ones with broad development prospect[4]. The energy storage density of sodium and sulfur is 140 kWh/m^3, volume reduces to 1/5 of ordinary lead-acid battery, system efficiency can reach 80%, monomer service life is long, and cycle life exceeds 6,000 times, easy for manufacture, transportation and installation in modularization, with short construction period, can install according to usage and construction scale in separated periods, is suitable for city transformer substation and special load. sodium flow batteries have small electrochemical polarization, can have deep discharge of 100%, has long storage life, mutually independent rated power output and volume, can reach the goal of increasing battery volume through adding amount of electrolyte or increasing concentration of electrolyte and can freely design storage type and randomly choose shapes according to the condition of set place. At present, sodium and sulfur and sap flow batteries both achieve business operation and MW-level sodium and sulfur and 100kW-level sap flow batteries energy storage systems have stepped into the period of demonstration already. With the expanding volume and scale, maturing of integration technique, the cost of energy storage system will be reduced. After the long-term test of safety and reliability, they are hoped to play an important role in aspects of improving wind/solar energies renewable energy's stability, smoothing user's side load and emergency power supply.

At present, energy storage equipment is hardly used in power systems, main reasons of which are two, first is the valuable price of equipment, so that we choose equipment with not too big volume and second is some technical and performance standards are too low to reach the requirements. But for the more and more important role it plays, some related departments are actively studying, developing and applying the technique. And we believe the future distributed energy storage equipment will be increased gradually and form distributed power and distributed energy system or micro grid system and it must play a good role in power system.

CONCLUSIONS

The social economic position of Shanghai decides Shanghai Power Grid has higher requirement on the reliability and quality of electricity energy and customer service need of power customers improve from time to time. After achieving distributed energy storage, customer can guarantee power supply through energy storage system under fault and repair of Power Grid, the safety and reliability of customers is greatly improved, power cut times (time) and power cut loss are reducing greatly while economic and social effect are obvious. Take Shanghai as an example, once the battery energy storage system forms scale effect, economic and social effect can be produced from the following aspects[5,6]: (1) effectively improve the utilization rate of available generation, transmission and transformation equipment, change the increasing model of power construction; (2) reduce the operation cost of generation enterprise and Power Grid enterprises, reduce the power fee of customers; (3) reduce the power cut loss; (4) energy-saving and emission-reduction.

Figure 1. Caoxi Energy Conversion Base

Figure 2. Grid energy storage system（SG-GESS system diagram）

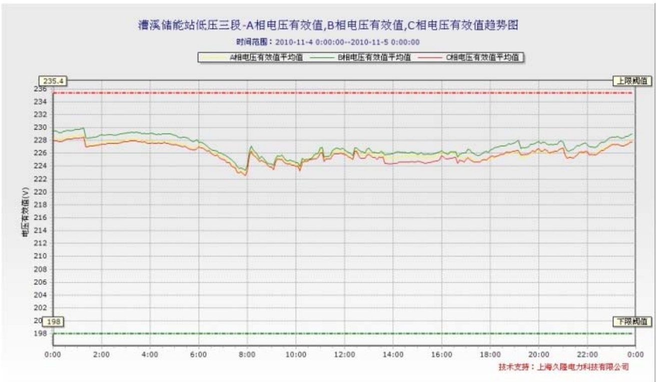

Figure 3. Valid Value of Three-Phase Voltage in the Analysis of Power Quality of Energy Storage System

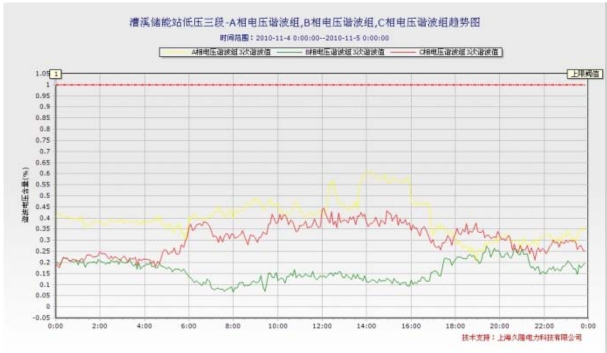

Figure 4. Harmonic Wave Group of Three-Phase Voltage in the Analysis of Power Quality of Energy Storage System

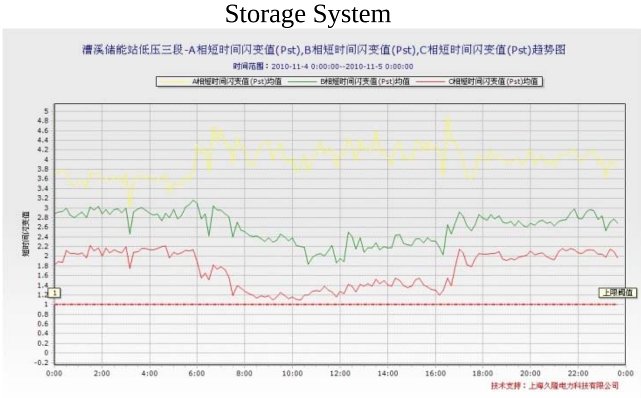

Figure5. Short Time Flicker of Three-Phase Voltage in the Analysis of Power Quality of Energy Storage System

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