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Economic Feasibility of Echelon Utilization Battery in Photovoltaic Energy Storage

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Abstract. Taking the power load of an industrial park in Shanghai as an example in this paper, particle swarm optimization and cost-benefit model are employed to analyse the economy of new lithium-ion batteries, echelon lithium-ion batteries and lead-carbon batteries in photovoltaic energy storage systems in the whole life cycle. The research results showed that the economic order from large to small among different batteries in the photovoltaic energy storage system was new lithium-ion battery, echelon utilization lithium-ion battery and lead-carbon battery. The declines in energy storage cost and discount rate and the rise in peak electricity price can greatly improve the net present value of a photovoltaic-energy storage system (PV-BES) system.

1 Introduction

By the end of 2019, the installed capacity of photovoltaic power generation in Shanghai has exceeded 1GW. It is worth noting that if the unstable photovoltaic factors are introduced into the stable power grid system on a large scale, the safe and stable operation of the power grid will be affected [1]. For example, when the uncontrollable photovoltaic is connected to the distribution network of residential quarters, there will be voltage fluctuation, flicker, reverse power flow and other problems. Therefore, battery energy storage system is a necessary technical solution. Although it is expensive for most families, it has more advantages than disadvantages as a buffer pool for variable photovoltaic power [2]. The echelon use of retired electric vehicles batteries is considered as one of the most promising ways to reduce battery cost by extending their service life [3]. In this study, the profit of pv-bes hybrid system is evaluated based on battery type, energy storage cost, discount rate and peak price. The evaluation results have important guiding significance for the further development of photovoltaic and bes industries.

2 Methodology and parameters

Photovoltaic system and battery energy storage system constitute a whole. The power consumption of the hybrid system includes first providing photovoltaic power to the load; the surplus energy is stored in the bes system and then sent to the grid. If photovoltaic power generation is insufficient, the energy stored in BES will be provided to the load first, rather than to the grid power supply. The batteries used in BES systems include new lithium ion (Li-ion), second lithium ion (Li-ion$_{2nd}$) and lead-carbon (Pb-C). Cost-benefit models for a PV-BES system and case study definition refer to the literature [4]. The parameter settings for different BES systems are shown in Table 1.

Table 1. Parameter settings for different BES systems.

Battery types	Li-ion	Li-ion$_{2nd}$	Pb-C
SOC$_{min}$ (%)	10	10	40
SOC$_{max}$ (%)	90	90	100
Lifetime (years)	10	5	5
Round-trip efficiency (%)	92	88	80
Unit cost (¥/kWh)	1800	200	1200

3 Results and discussion

3.1 Net Present Value Analysis

For comparative analysis, particle swarm optimization (PSO) is used to optimize the NPV of distributed PV-BES system with different BES (such as lithium-ion battery, lithium-ion battery and lead-carbon battery), as shown in Fig. 1, The results show that the NPV of distributed photovoltaic systems with different BES structures decreases in turn (Li-ion > Li-ion$_{2nd}$>Pb-C).

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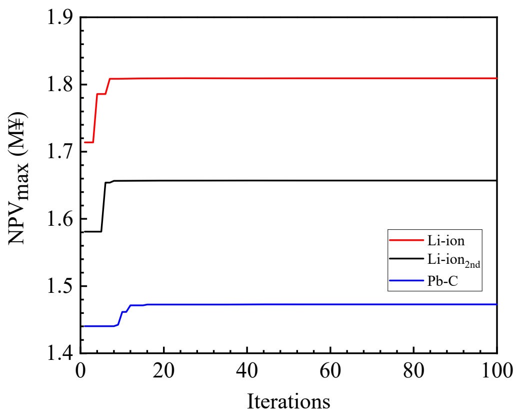

Fig. 1. The convergence curve of NPV_{max} of distributed photovoltaic system based on PSO algorithm..

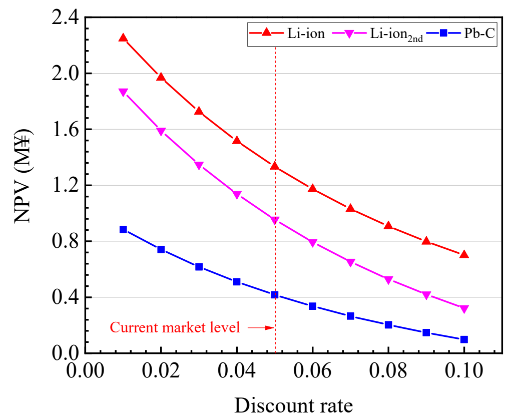

Fig. 3. Relationship of the NPV of a PV-BES system with different batteries with discount rate.

3.2 Influencing Factors of NPV

3.2.1. Battery cost.

Figure 2 shows the relationship between the NPV of PV-BES system with different batteries and the battery cost. The red dot at the bottom of each line in figure 2 represents the net present value of the PV-BES system in the current situation. NPV increases linearly with the decrease of battery cost, and Li-ion BES shows the maximum return of these three BES. The NPVs of Li-ion_{2nd} is more than that of Pb-C. Two decisive elements leading to low NPV of Pb-c-BES are shallow charge and discharge depth and low cycle life.

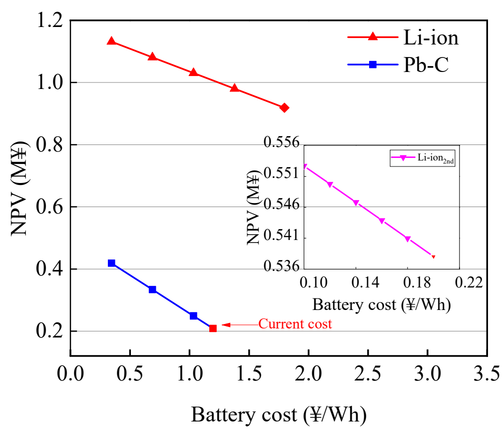

Fig. 2. Relationship of the NPV of a PV-BES system with different batteries with battery cost.

3.2.2. Discount rate.

Figure 3 shows the relationship between NPV and discount rate of PV-BES system with different batteries. At present, the discount rate is set at 0.08, as shown in the red vertical bar in Figure 3. It can be seen from Figure 3 that with the decrease of discount rate, the NPV of PV-BES system increases greatly; the NPV of PV-BES system will be doubled when the discount rate is reduced from 0.08 to 0.03.

3.2.3. Peak electricity price.

Generally speaking, the valley price is close to the cost of coal-fired power plants. Therefore, peak shaving price is a very advantageous scheme to balance power supply and demand and improve equipment utilization. Figure 4 shows the relationship between NPV and peak price of PV-BES system. In the current situation, the peak price is 1.106 ¥/kWh, as shown by the red vertical bar in Figure 4. Under the same growth rate of peak electricity price, Li-ion and Li-ion_{2nd} BESs can generate more profits than lead-carbon battery.

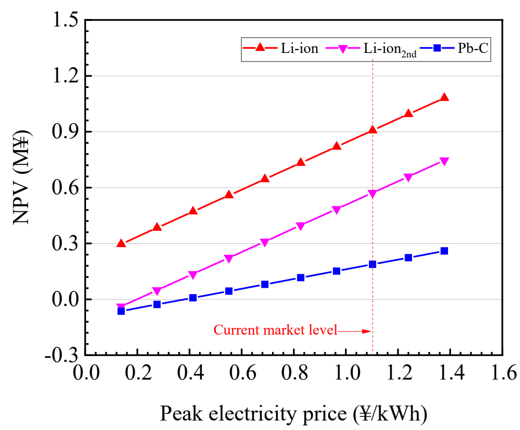

Fig. 4. Relationship of the NPV of a PV-BES system with different batteries with peak electricity price.

3.2.4. Energy storage subsidy.

Without the government's stimulus policy and financial support, it is impossible to cultivate and popularize a new technology. The prosperity of China's photovoltaic and wind power industries is an impressive example of active government support, such as subsidies for these types of energy [5]. By the end of 2017, China's cumulative installed capacity of photovoltaic and wind power reached 130gw and 188gw respectively, ranking first in the world. Therefore, the impact of government stimulus policies on the energy storage industry is emerging. Among all the government stimulus policies, the energy storage subsidy policy is often hotly discussed. Two schemes are proposed: one is to subsidize the energy storage according to the initial installed capacity of the BES system; the other is to subsidize the energy storage according to the energy release during the operation of the BES system. However, the specific level of energy storage subsidies has not been determined.

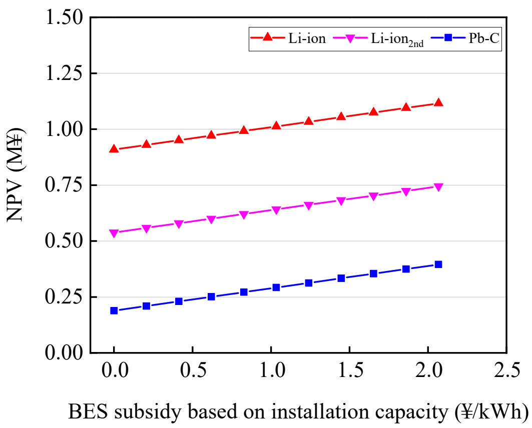

Fig. 5. Relationship of the NPV of a PV-BES system with different batteries with BES subsidy based on installation capacity.

Figures 5 and 6 respectively illustrate the dependence of NPV of PV bes systems using different batteries on BES subsidies based on installed capacity and energy released during operation. As can be seen from Figure 5, based on the installed capacity of the four bes systems, the NPV of PV-BES system increases in equal proportion to the increase of BES subsidies. However, the effect of BES subsidy based on discharge energy on NPV of PV-BES system is significantly different as shown in Fig. 6. The NPV of both Li-ion BES and Li-ion $_{2nd}$ BES distributed systems is more than that of Pb-C-BES. Among the four BES systems, Pb-C-BES shows that the growth rate of the same BES subsidy based on discharge energy is the lowest. The difference of energy storage subsidy benefits among different bes may be one of the reasons that detailed energy storage subsidy bill has not yet been issued. Most investors in the energy storage industry seem to prefer to invest in BES subsidies based on the initial installed capacity, because this will relieve the pressure on their capital pool to some extent.The BES subsidy based on the energy emitted during the operation period can not maximize the benefits of Pb-C BES, and the income growth rate under the BES subsidy is the lowest. Managers of government departments are more willing to promote the second act from the perspective of process management. In fact, the second motion is more reasonable than the first because the allowance in the second motion can be used for more work and encourage more work than the allowance in the first motion. In addition, in the second motion, the battery technology with high cost performance is preferred, because high performance Li-ion and Li-ion$_{2nd}$ BES will generate more profits than Pb-C BES.

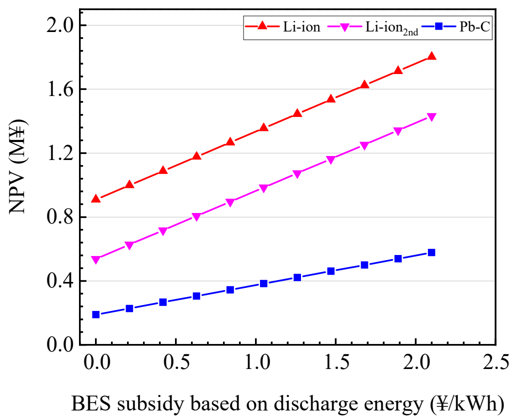

Fig. 6. Relationship of the NPV of a PV-BES system with different batteries with BES subsidy based on energy discharged during operation period.

4 Conclusions

(1) The NPV of distributed photovoltaic systems with different BES structures decreases in turn (Li-ion > Li-ion$_{2nd}$>Pb-C), due to the characteristics of these batteries.

(2) The declines in energy storage cost and discount rate and the rise in peak electricity price can greatly improve the net present value of a PV-BES system.

(3) Based on the generation and growth rate of these photovoltaic power generation systems, the generation of these power generation systems increases in the same proportion. The second bill on BES subsidies is more beneficial to the BES industry than the first one, because the implementation of the second bill can obtain more jobs and higher remuneration.

(4) The use of echelon battery in photovoltaic energy storage can not only prolong the service life of electric vehicle battery, but also greatly reduce the cost of photovoltaic power generation system.

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References

1. J Yaghoobi, M Islam and N Mithulananthan. APPL ENERG **211** 358-367 (2018).
2. AB Gallo, JR Simões-Moreira, HKM Costa, MM Santos. RENEW SUST ENERG REV **65** 800-822 (2016).
3. X Han, Y Liang,Y Ai and J Li. ENERGY **165** 326 (2018)
4. Q Liao,Y Zhang, Y Tao,J Ye,C Li. INT J ENERG RES **43** 6461-6474 (2019).
5. X Zhao, Y Zeng, D Zhao. ENERGY **88** 572-583(2015)