The Research on Energy Storage System Providing Value-Added Application Services for System Operation

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1. Research Background

Under the energy policy plan in Taiwan, the penetration rate of renewable energy installations is expected to exceed 20% by 2025, which will bring greater challenges to the frequency regulation and balance between supply and demand of the power grid. Energy storage technology has become increasingly important due to its rapid response and flexible dispatching characteristics. The launch of Energy Trading Platforms and the increase in investment in energy storage facilities by external players have gradually revealed Taiwan Power Company's role as a system operator. It may help promote energy transition and stable development of the power system.

2. Research Content

This research aims to assist Taiwan Power Company in strengthening the dispatch application of energy storage technology in the domestic power system. The main research objectives include 1. improving the planning structure and specifications of existing ancillary services, 2. analyzing the application methods of real-time dispatch and technical specifications, and 3. proposing specific suggestions for incorporating energy storage applications into power dispatch or trading.

The research contents include collecting international ISO (Independent System Operator) energy storage application cases, analyzing the implementation effectiveness of existing domestic energy storage, developing application methods of energy storage in the domestic power grid, conducting simulation analysis with Python and Matlab, and researching the adjustment recommendations for technical specifications in energy storage applications. Through the aforementioned methods and planning, we can further understand the application of energy storage in the domestic power system and serve as a reference for developing future rules.

3. Research Findings

1. Research and analysis of international ancillary services and real-time dispatch practices

According to several international ISO

practices collected by this research, in terms of auxiliary services, the UK case is worth noting for the detailed division of labor in regulation and frequency response services, clearly dividing the backup function into pre-accident and post-accident usage scenarios and increasing the implementation rate requirements. Australia has also added a one-second rapid response service to incidents. The worth noting thing is that when adding new ancillary services, the conditions of the market and participants are considered carefully. Although there are no unified technical specifications for providing virtual inertia from energy storage among international power systems, it is possible to understand the capability requirements and operating conditions between the inertia provided by energy storage and ROCOF (Rate of Change of Frequency) from the technical literature. On the other hand, for real-time dispatch, the composite dispatch methods of Texas and New York provide significant reference values for developing domestic energy storage E-dReg. The high proportion of renewable energy causing night peaks is also a major issue in California. The scheduling and dispatch method of energy storage is worth following up on.

2. Analysis of energy storage execution effectiveness

The execution effectiveness of existing energy storage can be divided into individual operation analysis and overall energy storage contribution analysis. For individual operation of energy storage, the execution rate is mostly higher than 90%. The reasons for the low execution rate can be summarized into five factors: too high or too low SOC, frequency detection problems, charging and discharging settings, operating point deviation, and other operating abnormalities. Therefore, this research will include the development of implementation rate standard improvement in subsequent work, aiming to improve the energy storage's operating effectiveness. On the other hand, the analysis results of the overall energy storage contribution show that the data distribution of system CPS1 has increased compared with the same month in previous years, and the distribution is more concentrated, showing that the frequency change rate has a decreasing trend; during the accidents, within a few seconds, the energy storage can operate nearly at full power output, the frequency deviation of medium-sized accidents is reduced from 0.3Hz in 2022 to approximately 0.2Hz in 2023, which suggests the overall benefit of energy storage on system frequency.

3. Energy storage dispatch scenario simulation

The establishment of the power grid and energy storage dispatch function model is applied to the simulation of four different energy storage dispatch scenarios, namely dReg, sReg, E-dReg, and virtual inertia, which is helpful for the quantification in this study. The model architecture is shown in Figure 1, and the simulation results are explained in the fifth point of this article.

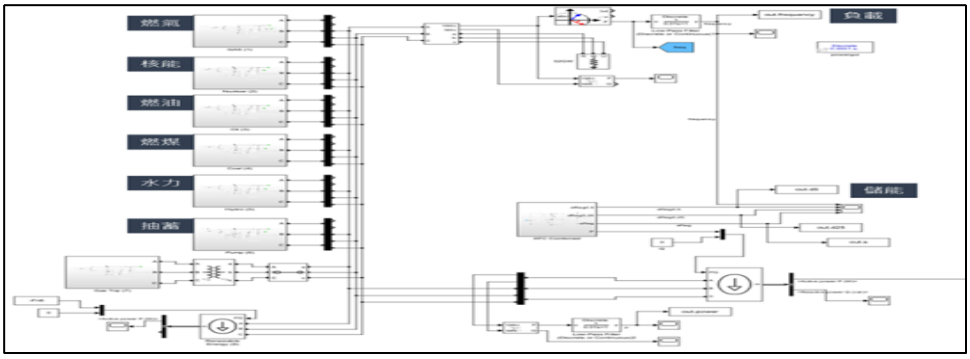

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Figure 1 Power grid and energy storage dispatch function model

4. Improved practices in auxiliary services

This research also explores the improvement of the regulation reserve, focusing on the adjustment direction of the auxiliary services, the enhancement of the dReg execution rate, and the functional verification of sReg and E-dReg. First, the adjustment direction of auxiliary services is based on the practices of the UK and Texas. Comparing the differences in technical specifications, the analysis results show that the domestic practices are similar to foreign trends and can achieve similar frequency stabilization effects. The dReg execution rate enhancement is based on UK practices. The method is viewed in a four-second rolling manner, as shown in Figure 2. The existing energy trading platform has introduced the actual rules since October 2023. The analysis of sReg mainly explores the start and stop conditions under the existing frequency scenario. The impact of increasing or decreasing the trigger frequency on energy storage is analyzed. E-dReg verifies its feasibility through numerical analysis and field testing, as shown in Figure 3.

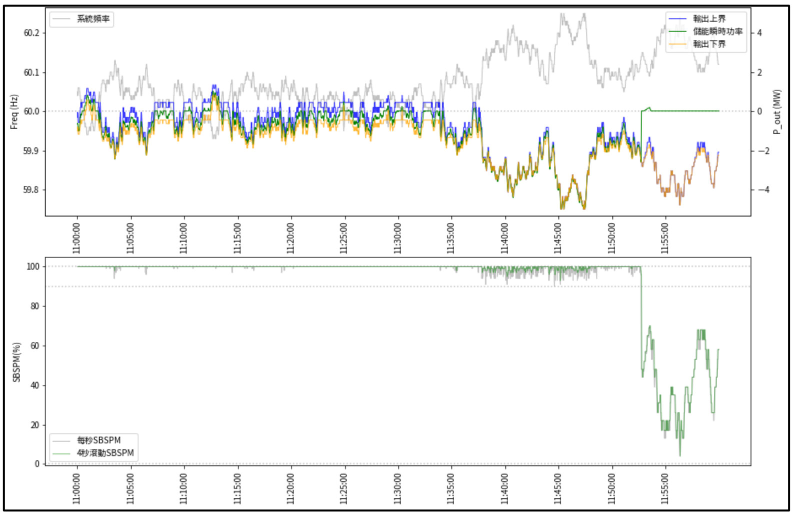

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Figure 2 Analysis of energy storage operations per second with dReg execution rate enhancement

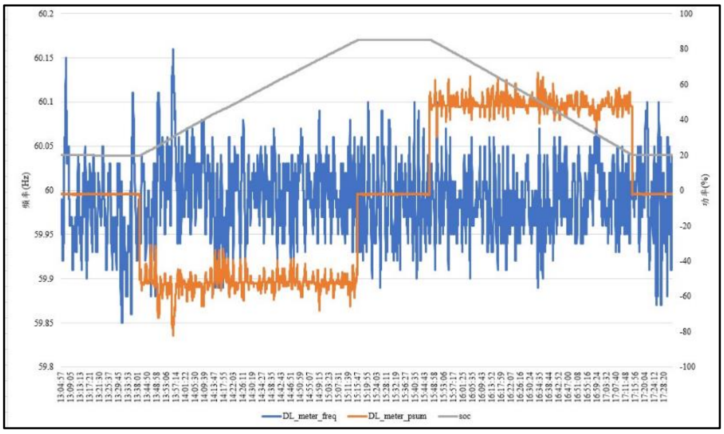

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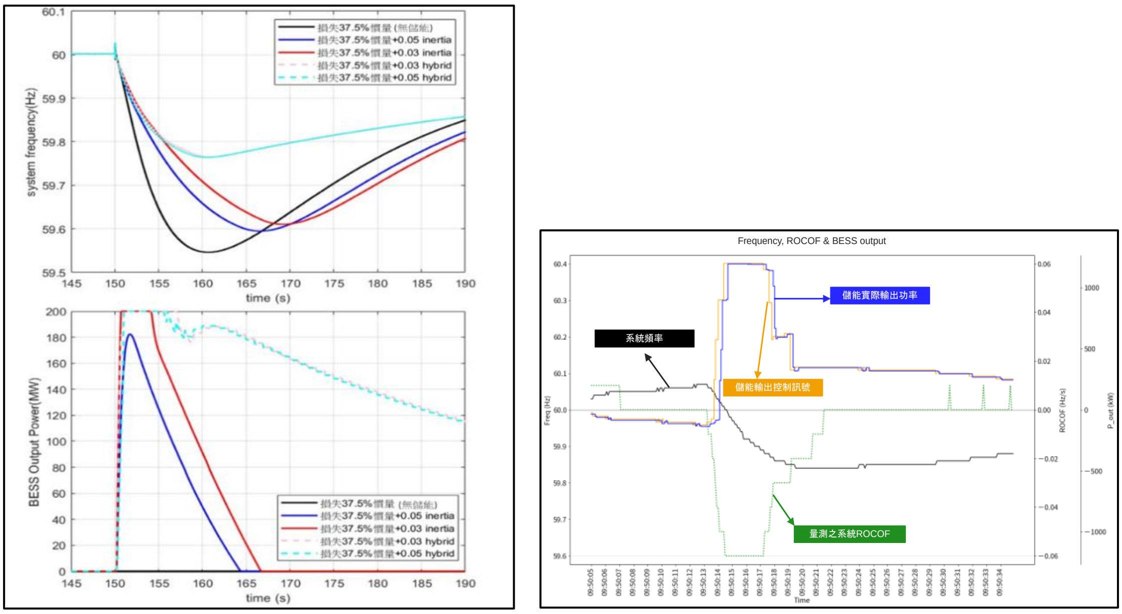
Figure 3 The output waveform of the E-dReg test conducted by Yongan Energy Storage

5. Research on the future dispatching function of energy storage

For the development of future dispatching functions, the functions mainly discussed in this research include virtual inertia, voltage adjustment, and load following. To analyze virtual inertia, this research uses ROCOF to design technical specifications based on literature and historical accident frequencies, including deadband and full output conditions. Then it conducts research using power grid model simulation and field testing, as shown in Figure 4. The results show that energy storage can operate according to the technical rules formulated by this research and have the potential to be introduced into existing energy storage fields. The voltage adjustment is an existing requirement of the grid connection rules, and the research will further complete the voltage analysis of the energy storage case and field tests to verify its feasibility. Load following aims to achieve real-time supply and demand balance through energy storage, and a PI controller was designed to control the energy storage output power. The research results show that it is technically feasible, and relevant rules can be implemented based on the actual needs of the power grid.



(a) Virtual inertia power grid model simulation results (b) Actual energy storage field test results of virtual inertia

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Figure 4 Simulation and field test results of virtual inertia provided by energy storage