The Demonstration and Verification of Energy Storage System at Fengshan Smart Green Community

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(i) Introduction

To cope with the Executive Yuan's smart energy-saving policy, the "Sustainable Smart City Plan", the Department of Construction, Taiwan Power Company (TPCDC), based on the energy-saving improvement technology of old buildings, selected the Fengshan dormitory managed by Dalin Power Plant, Xingda Power Plant and 3rd Nuclear Power Plant and the Fengshan District Sales Office(FDSO) as a smart green community technology demonstration base (an area of about 6.75 hectares). With the optimization of energy, smart management system, well-being community, and self-technologies as the main axis, the base will be built as the first smart green community in Taiwan. The project received a subsidy of 29 million NTD by "Sustainable Smart Community Innovation Demonstration Project" of Architecture and Building Research Institute, Ministry of the Interior in 2019.

This project plans to build a "domestic energy storage system" and a "small community energy storage system" in Fengshan dormitory area, as well as an "enterprise energy storage system" in FDSO in 2019 to exhibit a variety of energy storage system patterns. The solar photovoltaic at FDSO is estimated to be able to build 600 kWp, 7 grade-B dormitories in the area of logistics can build 200 kWp. Taipower Research Institute (TPRI) has accumulated extensive experience from its green energy ecological park and Shulin micro-grid building storage energy verification demonstration system. TPCDC entrusted TPRI to handle the establishment of solar photoelectric and energy storage system, and carry out relevant information collection, analysis and evaluation, as the basis of the promotion and applications of other fields. This paper introduces the completion of the high-voltage substation renovation, 600k Wp solar photovoltaic and 1MWh lithium battery energy storage system construction work at the end of February 2020 in FDSO, and the progress and effectiveness of the intelligent energy management system, to achieve the goal of installing Fengshan smart green community.

In order to achieve the expected goal of this project, based on the research and development ability of TPRI in distributed microgrid, TPRI thus conducted this typical self-research project. The research content planning, research and development budget to physical construction and even site construction supervision were all completed by TPRI's research colleagues. This study plans to construct 1 set of 800kWp "High-performance grid-connected solar photoelectric system " (75,228 thousand NTD, including roof waterproof application of 6 buildings in FDSO and of 7 grade B dormitories), and I set of "500 kW/1MWh lithium-ion container type electrical energy storage system (52,300,000 NTD, including the reconstruction of a high-voltage substation in FDSO, completed on March 2, 2020 and then connected to grid on April 1 after the test-run optimization.

(ii) Research methods

Based on the needs of the TPCDC, TPRI proposed a two-year research project including power load analysis, energy conservation assessment, solar photovoltaic construction, energy storage system functional detail design, and energy management architecture design. The physical construction started in 2019, and completed in April 2020. The contents of the project are as follows:

1. Redraw the single-line diagram of the electric power at FDSO: It is used as an electric load analysis survey to understand the electricity demand. The results of electric load analysis revealed the load distribution. Analyze the characteristics of the field to find out the relevant characteristics of buildings, personnel and equipment, and evaluate the possible space for energy saving.
2. Solar photovoltaic installation: By installing pyranometer and thermometer at the installation site,

we can estimate the possible power generation amount, and install solar photovoltaic power generation module to integrate the power fluctuation data.

3. Functional design and system construction of energy storage systems: This item conducts battery energy storage system construction for applications such as disaster prevention, voltage regulation, peak and valley arbitrage, backup power, ups, auxiliary services, solar smoothing, and replacement of diesel generators.
4. Energy management architecture design: This item emphasizes the essential functional design, including energy visualization, green energy maximization, island operation, and suppression of peak power consumption, etc., as well as battery performance characteristics such as energy consumption analysis, efficiency, and performance variation, etc.

(iii) Research results

1. The re-drawing of the single-line diagram of electricity in FDSO: The lack of a complete electric single-line diagram in FDSO will cause trouble for certification and electricity audits of solar photovoltaic and energy storage system technicians. After several consultation meeting, the budget will be implemented in this research plan. This item entrusted the Juding's electric engineer office to redraw electric single-line diagram of the 11.4kV high-voltage main substation and feed lines of various buildings in FDSO. It has completed the 11.4kV power feed lines and high-voltage substations of various buildings (including low-voltage electrical rise maps), and record relevant information, including the power distribution building, material building, business building, repair factory building, power distribution dispatch center building, union office and parking shed, etc. The work was completed at the end of May 2019, and all paper and electronic files had been sent to FSDO.
2. Reconstruction of high-voltage substations: In order to cooperate with the construction of solar photovoltaic and energy storage systems, the coordinated protection of high-voltage substations at FDSO and the high and low voltage side lines need to be designed and reorganized. To pre-prepare for the subsequent smart microgrid, it was also arranged in the energy storage construction case of this research plan. The case was completed in March 109 (the high-voltage substation before and after reconstruction is shown in Figure 1), which has a considerable improvement in vision and function.
3. Solar photovoltaic installation: According to the research plan, a solar photovoltaic system with a capacity of 600kWp will be installed in the power distribution building, material building, office building, repair factory building, power distribution dispatching center building, labor union office and parking shed at FDSO. The 7 buildings of grade-B Fengshan dormitory with 200 kWp in the left of Figure 2 and the right of Figure 2.
4. Functional design and system construction of energy storage system: The specification of the energy storage system is 500kW/1MWh. This system uses the lithium ternary battery cell manufactured by Delta Electronics in Taiwan with a single battery capacity of 60Ah. 14 single cells are connected in series to form a battery module, and 17 battery modules are connected in series through a copper bar to form a battery cabinet. In the 40-foot container of this energy storage system, a total of 26 cabinets are connected in parallel, DC side voltage up to 900~1000VDC, total power capacity up to 1000 kWh, through 4 sets of 125kW power condition system with 3-phase 480VAC/500kW rated power input/output capability, after boosting and grid-connected the system has fed into 11.4 kV substation. The power supply circuit can be used to adjust the electricity consumption in the area. The appearance of the device is shown in Figure 3.
5. Energy management architecture design: The energy management system page is shown in Figure 4 and Figure 5. Figure 4 is the home page, the screen shows the real-time information at 12:56 on 4/14, 109, and the screen shows noon at FDSO. At that moment, the power consumption is 91 kW, the solar power

generation is 378 kW, and the proportion of green energy has reached 100%. There is no need to be supplied by the grid power. The excess power is stored in the energy storage system to supply the nighttime needs. The system officially launched on April 1, 109, and the accumulated green power supply accounted for 72% by 4/14. Figure 6 is the solar photovoltaic power generation record and power analysis page. From the power analysis data, it is known that the average value of solar photovoltaic efficiency on that day is about 80%, and it can be completely supplied by solar energy during the day. According to the record data, the weather conditions on April 12 and April 13 are good, and the storage of the energy storage system on April 13 is released until 3:00 in the morning on Aprol 14. On April 13, the main electricity was used only in the district from 2:30 to 6:00 in the morning. This reveals that FDSO is a typical smart microgrid with a high solar photovoltaic ratio.

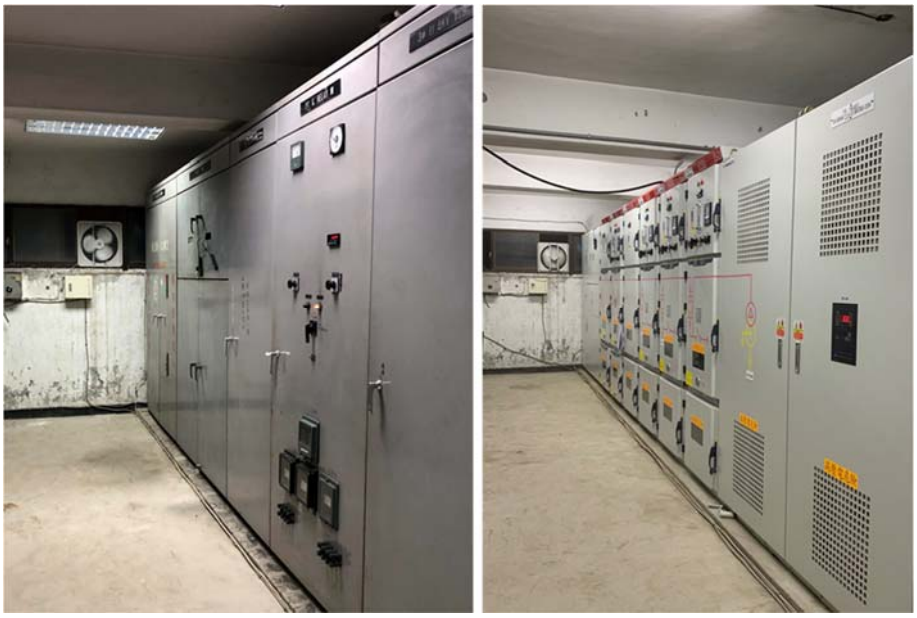

Figure 1 Before (left) and after (right) renovation of the high-voltage substation at FDSO

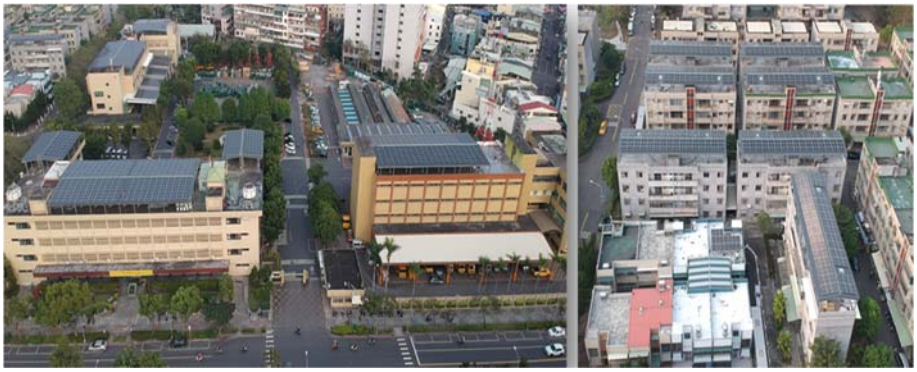

Figure 2 Photograph of 600kWp-PV(left)，Photograph of 200kWp-PV(right)

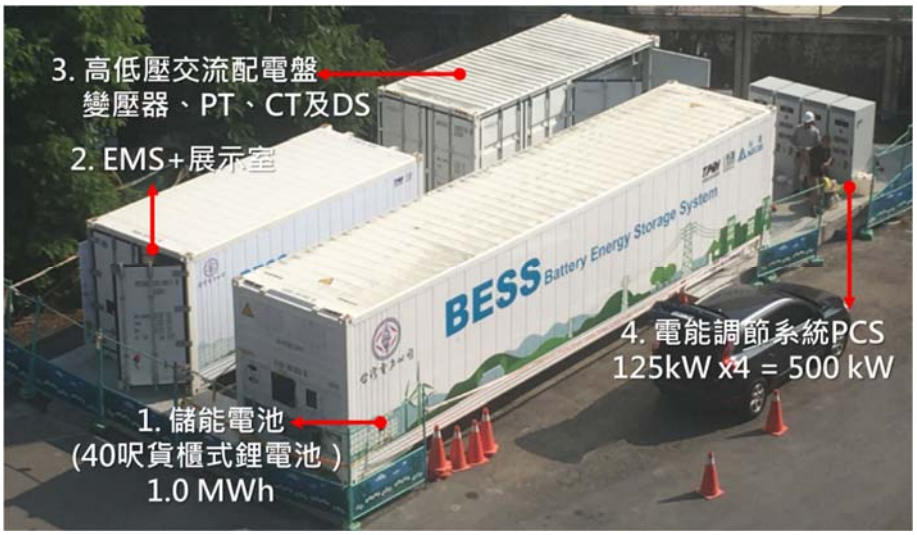

Figure 3 The 500 kW/1MWh lithium-ion container energy storage system

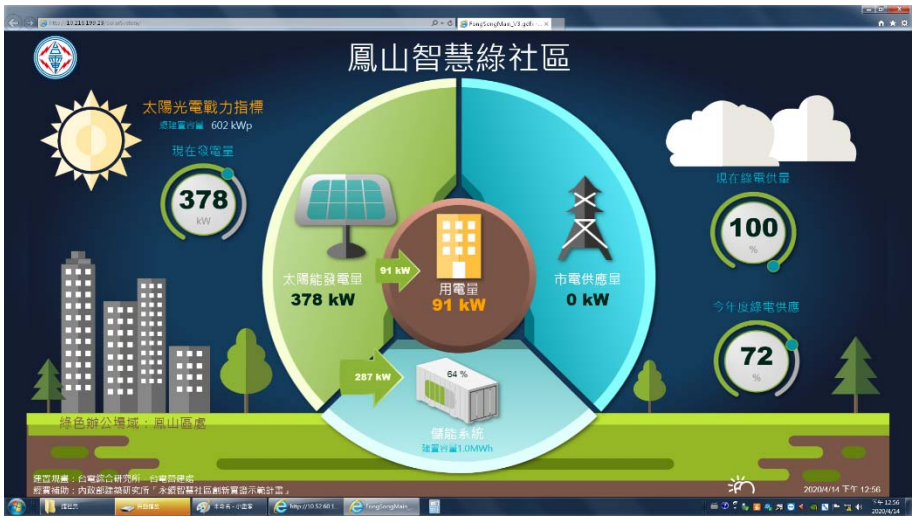

Figure 4 Home page of Energy Management System

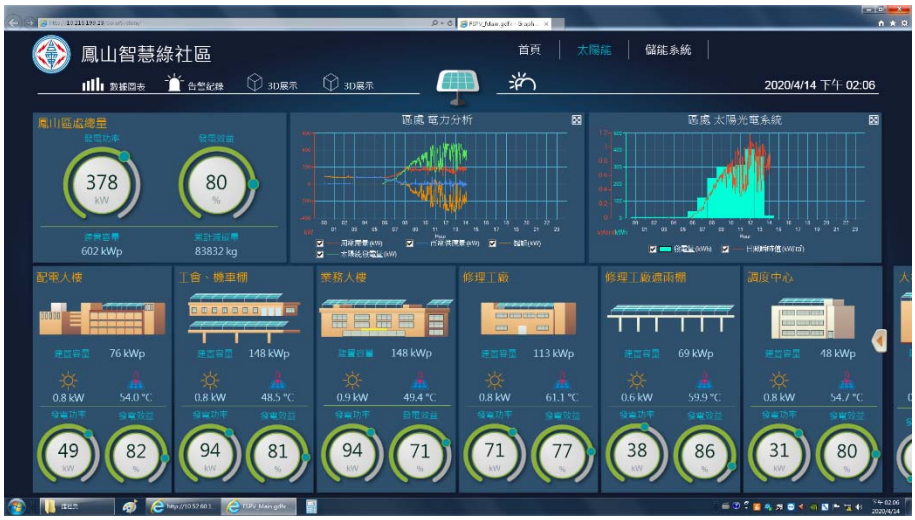

Figure 5 Solar photovoltaic power generation records and power analysis in FDSO