All-in-one Power Conversion System for a Smart Factory

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Abstract. This paper investigates the incorporation of a PV-ESS linked, all-in-one power conversion system (PCS) at a small factory, in an attempt to improve the factory’s resilience against the increase in load due to facility expansion. The aforementioned factory was installed with 210kWh PV and 550kWh ESS, both of which were simultaneously managed by 250kW hybrid power conversion system. This independent operation of the factory through the PCS was proven to be efficient and economical, because of the reduced power usage and the sale of surplus electricity.

1. Introduction

The renewable energy system industry has been exploding in size in response to the recent upsurge in the global demand for electricity. In particular, the market for integrated system of PV (Photovoltaics) and ESS (Energy Storage System) has been growing at an annual average rate of 20% in Southeast Asia and the Middle East, as increasing number of people have been charmed by the applicability of the integrated PV and ESS system for either independent or grid-dependent operation.

The technology of Hybrid Power Conversion Systems (PCS) so far, however, has been developed primarily for high-capacity ESS that handles electricity in the order of Megawatts (MW). Thus, while the demand for smaller ESS (which power in the order of hundreds of kW) is increasing worldwide, the research for said technology has been insufficient and the installation cases of the lower-capacity PCS Therefore, an integrated system of 210kW PV, 550kW ESS, and a compatible All-in-one PCS, capable of operating independently or dependently of grid connection, was installed at a small factory. The installed system was then operated and examined in order to study its applicability, efficiency, and readiness for real world use.

2. All in one Power Conversion System

2.1. Factory introduction

The All in one PCS was installed at a small factory located in Cheongyang, Chungcheongnam-do, Republic of Korea. The factory was using a simple 250kVA power reception facility, but aims to expand its production facilities in the near future. As a countermeasure against the consequential increase in load, the following were installed: PV power generator as a renewable energy source, ESS as a storage for the gathered electricity, and Hybrid PCS for the power management.

2.2. Configuration of the All in one PCS

Figure 1 depicts a diagram of the system configuration. The system consists of a 210.6kW PV power generator composed of 390W PV modules, and ESS composed of four 137kWh battery racks, and a
250kW Hybrid PCS using 3P4W power. PV panels were installed on the factory roof in order to utilize unoccupied part of the existing facilities, instead of sacrificing factory site that should rather be reserved for facility expansion. Hybrid PCS and ESS were each loaded inside a container equipped with air conditioning and fire prevention equipment. Table 1 and Table 2 show the electrical specifications for the components of the All in one PCS system.

![250kW Hybrid PCS / 548kWh ESS](image)

**Table 1. ESS Specification**

| ESS Specification                  | Value                          |
|-----------------------------------|-------------------------------|
| Voltage range [Vdc]               | 588–823.2                     |
| Nominal Voltage [Vdc]             | 725.2                         |
| Maximum charge/discharge power[kW]| 274.008                       |
| Nominal charging state            | CC-CV, Charge Current: 56.7A(0.3C) |
| End Voltage/Current: 823.2V / 9.45A(0.05C) |     |
| Nominal discharge state           | CC, Discharge Current: 56.7A(0.3C) |
| End Voltage: 588V                 |                               |
| Total Rack Energy[kWh](nominal)   | 548.016                       |
| Communication Protocol            | CAN                           |
| Protective Function               | OC, OCH, ODC, OH, SP          |

**Table 2. PCS Specification**

| PCS Specification          | Grid-connected |
|----------------------------|----------------|
| Type                      | MPPT           |
| DC Input                  |                |
| Input voltage range       | 550–850V       |
| Operating Voltage range   | 600–850V       |
| AC output                 |                |
| Rated Output              | 250kW          |
| Efficiency                | 95.91%         |
| Power factor              | 0.99           |
| Total Harmonic Distortion | 2.3%           |

![Figure 1. Configuration diagram of the All-in-one PCS](image)
Maximum Harmonic | Single Harmonic | 1.95%
---|---|---
Protective function | OV, UV, OC, OT, OF, UF | |
Communication Protocol | Modbus RS-485 | |

3. All in one PCS system Operation
The Hybrid PCS was run according to the schedule shown in Table 3., which was tailored to the characteristics of small factory and its daily load pattern. The ESS was charged during the period when the solar power generation efficiency is at its highest (09:01-16:00). In addition, 5kW of power was discharged every hour to partially compensate for the load necessary to power the factory during operation hours, except during the downtime (05:01-06:00), which exists to rest all machines and equipment for safer operation. Lastly, the remaining energy stored in the ESS during the charging period are all utilized in the following morning (06:01-09:00), thus securing the economic feasibility as a power producer as well.

Table 3
| PCS Operation Schedule |
|-------------------------|
| **00:01 – 05:00** | ESS discharge, 5kW/hour |
| **05:01 – 06:00** | Operation break for safety |
| **06:01 – 09:00** | ESS discharge, 5kW/hour |
| **09:01 – 16:00** | ESS Charging from PV |
| | PV power transfer to customer, 5kW/hour |
| **16:01 – 20:00** | ESS discharge, 5kW/hour |
| **20:01 – 00:00** | ESS discharge, 5kW/hour |

Figure 2 illustrates the change in SOC of ESS that occurs over a few cycles of the charge-discharge schedule shown in Table 3. The graph confirmed that the ESS charging and discharging proceeds as intended, therefore proving the economic feasibility of the system as a power generation business.

4. Conclusion
In preparation for the load upsurge of a small factory using KVA-sized power reception equipment, the all in one PCS system including Hybrids PCS that can control PV and ESS was built, and the actual
operation was carried out. As a result, independent operation using PV power generation was proven to be able to efficiently reduce the existing factory load, and by conducting ESS charging and discharging throughout 24-hour cycles, the system was confirmed to be capable of generating enough electricity to the extent to which the surplus energy can be sold for economic revenue. Even if the load used in the factory increases due to the future expansion of production facility, the All-in-one system is expected to effectively manage the heavier power load through the combination with grid connection.

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References
[1] Seong-Yong Lee, Myung-Ho Woo, Seung-Pyo Ryo(2015), Development & Demonstration of ESS-PCS Controller for Industrial Customer. Power Electronics Conference, pp.225-226.
[2] J.H.So, Y.S.Jung, G.J.Yu, M.W.Jung, G.H.Kang, J.Y.Choi(2003), Performance Analysis of Grid-Connected PCS for PV System by Field Demonstration Test. Power Electronics Conference, pp.516-519.
[3] Seokyong Hong, Daeki Yang, Seungyeong Yu, Sehyung Jung, Minkook kim, Seongjin Oh, Sewan Choi(2018), DC Common Method of Hybrid PCS Overseas Demonstration Operation. Power Electronics Conference, pp. 348-349
[4] Sungmin Cho, Chulwoo Kim, Yongbeun Yoon, Byunghoon Chang, Sooyeol Kim(2015), Specification design of PCS and Battery for Gochang 54MW BESS. KIEE Conference, pp.148-149