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Development and demonstration of distributed power connected intelligent UPS algorithm

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Abstract

It is a system that can simultaneously implement the functions of ESS (Energy Storage System) and UPS (Uninterruptible Power System). ESS can increase energy efficiency by supplying power when needed. The UPS can supply stable power even in the event of a sudden power outage. In this paper, we propose a distributed power-linked UPS system that can generate profits through distributed power while performing the basic functions of the UPS. We designed an algorithm that can change the UPS capacity according to the amount of distributed power generation and can generate the maximum profit. The basic function of the proposed algorithm follows the operation mode of the economical creation mode, Normal mode, and the uninterrupted transfer function mode in case of power failure. In addition, we proposed an algorithm that enables load reduction and active UPS capacity calculation based on PV power generation for active response. Based on the designed algorithm, the operation state of each mode was verified using PSIM (Power electronics simulation). To verify the proposed system, a verification site was built and verified through experiments. As a result, it was confirmed that idle power can be used when the proposed algorithm is applied. In addition, it is expected to contribute to vitalization of the UPS market as additional revenues such as installation cost recovery are created.

Keywords: UPS(Uninterruptible Power Supply), ESS(Energy Storage System)

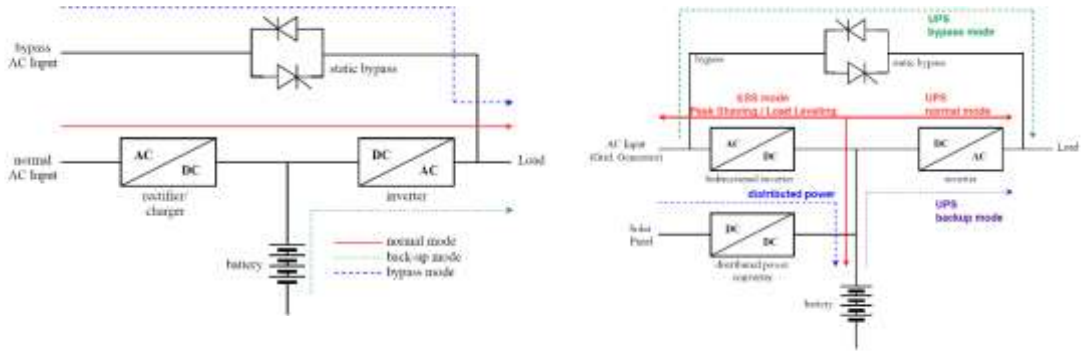
1. Introduction

Modern society is becoming informational and industrialized. Accordingly, the use of loads that are sensitive to the power environment such as domestic Internet data centers, medical equipment, and communication equipment are continuously increasing. As a countermeasure against this, the demand for an uninterruptible power supply (UPS) capable of supplying reliable power is rapidly increasing. The uninterruptible power supply is a device installed to always supply normal power to a device in use when an excessive voltage drop occurs due to a power outage or an accident. However, because UPS is used only in emergencies, its utilization rate is low compared to the investment cost. The structure and operating principle of ESS and UPS are similar in that power is stored in a battery and used when necessary[1][2][3]. ESS has a structure that converts renewable energy sources into high-quality power, stores them in a battery, and supplies them back when needed. The UPS stores power in batteries and supplies high-quality and stable power to loads sensitive to the power environment, such as large-scale power outages during peak loads in summer and winter[4][5]. However, UPS is a device that supplies power to major loads without interruption in the event of a power outage, and is installed with an emergency in mind, so the utilization ratio is very low compared to the investment cost. To compensate for these shortcomings, if t]he UPS and ESS are integrated and built, the battery utilization rate can be increased[6][7]. In the case of a UPS of 50KVA or higher, additional facilities such as a power converter and battery are required, and it is urgent to develop technology that can be operated at all times through a modular UPS design that is not limited to emergency use and can expand capacity.Existing ESS and UPS have a common energy storage system, but there is a difference in circuit configuration and control method of the power converter.Therefore, it is necessary to develop a structure and algorithm that can be used at all times, free from the constraints of an emergency power source, change the UPS capacity according to the amount of power generated by the distributed power source, and generate profits (VPP, DR, E-prosumer). When the UPS and ESS are combined and operated, it is necessary to study the operation algorithm for each mode by analyzing the load characteristics of the application site. In this paper, an automatic capacity estimation algorithm was designed considering economic feasibility[8][9]. The basic function follows the Operation Mode in Normal mode and UPS mode[10].We propose a distributed power-connected UPS system capable of generating profits through distributed power while performing the basic functions of the UPS. This system changes the capacity of the UPS according to the amount of power generated by distributed power, and is structured to generate maximum profit. To verify the proposed system, a verification site was built and verified through an experiment.

2. Main Subject

2.1 *System Basic Configuration*

Figure 1(a) shows the configuration of a conventional UPS system. Figure 1(b) shows the configuration of the intelligent UPS system connected with distributed power proposed in this paper. This system normally operates as an ESS. In addition, load leveling and peak shaving are performed, and the frequency of use and utilization are high. It can be directly connected to DC distributed power and can generate profits.ESS and UPS have a common point of storing energy, but there are differences in circuit configuration and control method. Therefore, it is necessary to modify the control method to perform both functions at the same time.



(a) **(b)**

Figure 1. System configuration of modular UPS linked to distributed power

2.2 *Distribution panel design for linking with distributed power and UPS*

Figure 2 shows a block diagram of an input/output separate type distribution board. The structure for separating the input line and output of the integrated system was selected. The input side distribution panel for three-phase grid power and PV power generation input and the output side battery distribution panel for connecting the output of each UPS and PV distributed power system to the battery bank were separated.

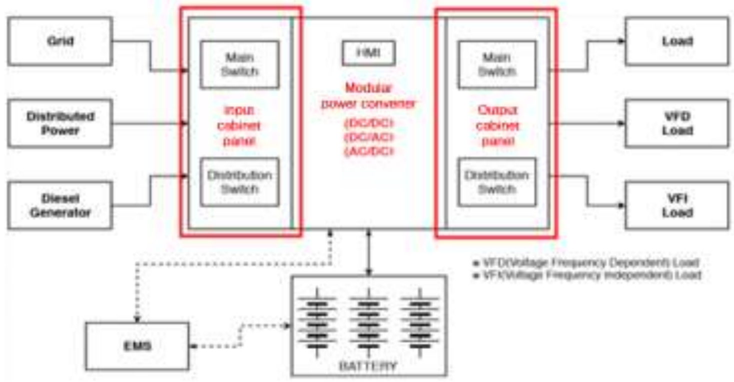


Figure 2. I/O separation type distribution board block diagram

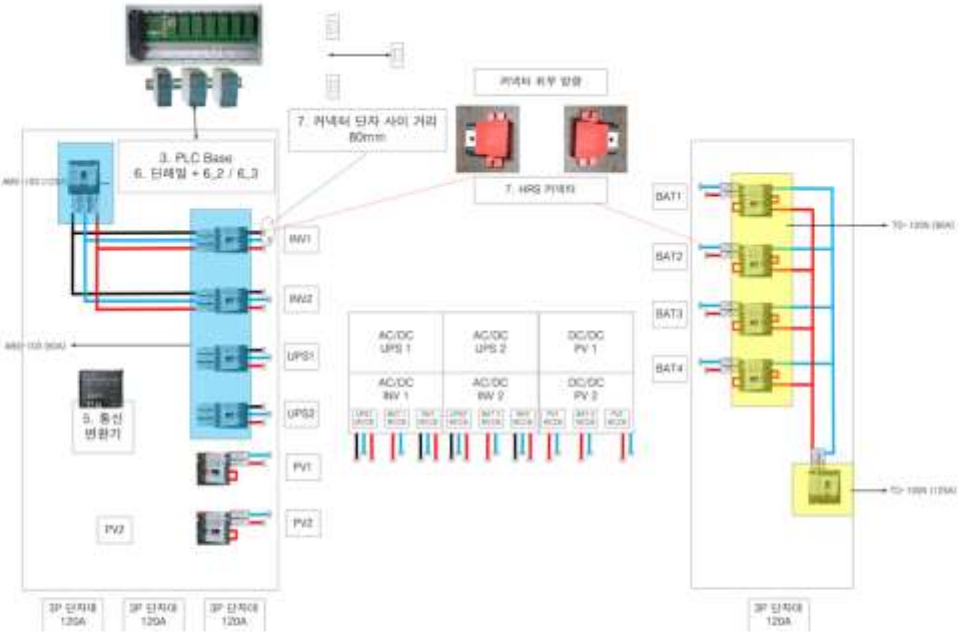
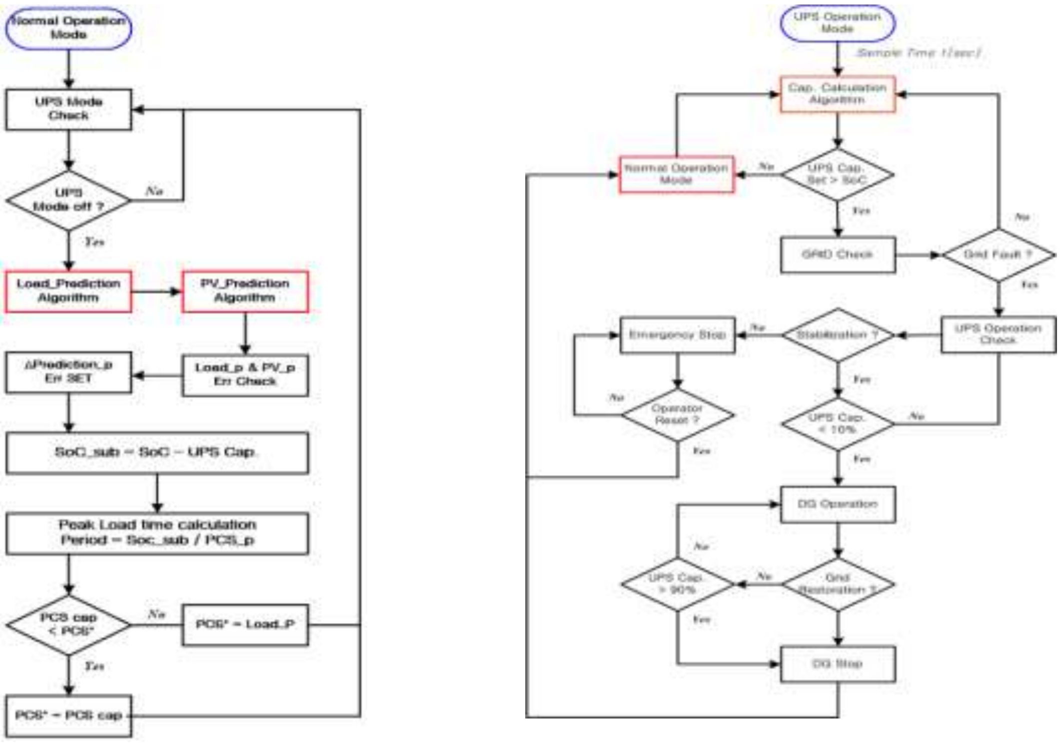


Figure 3. I/O separation type distribution board structure

Figure 3 shows the structure of the I/O separation type distribution board. In accordance with the design of the UPS and inverter, the primary separation type distribution board structure with the connection structure for each connector terminal of the system direct connection method applying the input/output separation type was selected. It is composed of monitoring units composed of power supply and PLC, HMI, etc. for the operation of monitoring modules inside the distribution board. The unit for monitoring was changed from the front panel arrangement of the distribution panel door to the structure to be directly mounted on the inner panel inside the distribution panel. And to minimize the interference between each branch line when connecting the connector directly from the outside, the breaker extension bus bar and the separation distance were secured, and the interference was minimized by setting the spacing of the connector mounting parts.

2.3 ***Supply capacity automatic calculation algorithm***

Figure 4 shows the basic algorithm design considering economic feasibility. Internal/external power consumption factors were analyzed through application load pattern analysis, and operation algorithms for each mode were established. Figure 4(a) shows Normal Operation Mode for energy saving because both the UPS function and the profit generating function must be satisfied. Normal Operation Mode is operated as an operation mode to create economic feasibility at all times by combining with a power source by applying an algorithm for ESS capacity design and operation mode. First, the initial driving mode is set by dividing it into summer and winter seasons. It is operated through the application load amount and PV generation amount prediction algorithm. Check the error of load and PV power, and estimate the amount of power by calculating the peak load time. Figure 4(b) is an algorithm design of UPS Operation Mode that prevents damage from blackouts and system malfunctions and provides stable power supply during peak loads in summer and winter.In case of problems such as power failure or system malfunction, the UPS Operation Mode operates in the uninterrupted transfer function mode and performs its original function. It operates in the UPS mode in case of a grid accident by checking the energy and SOC stored in the UPS.In the proposed Normal Operation mode, which departs from the original function of the UPS, it calculates the amount of time that can be supplied compared to the current energy storage by predicting the generation and consumption of the power source and load, and automatically supplies it to the load.It was designed to satisfy both functions by leaving the capacity of the ESS required in the UPS operation mode.



(a) **(b)**

Figure 4. Basic algorithm design considering economic feasibility
(a) Normal Operation Mode, (b) UPS Operation Mode

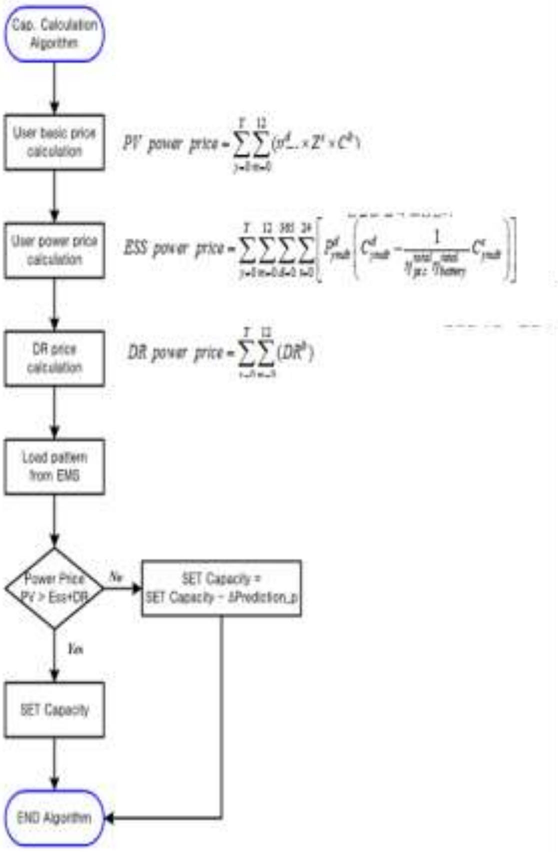


Figure 5. Design of Algorithm for Automatically Estimating Supply Capacity

Figure 5 shows the load reduction and power trading sequence. The basic function of the algorithm applied in this paper follows the Normal Mode and UPS Operation Mode. However, in this mode, the UPS secured area is lowered during the PV generation period, and the UPS capacity is secured again after the PV startup time. That being said, it is impossible to take an active response based on the current amount of power generlation. herefore, the proposed algorithm adds an algorithm that can reduce the load and proposes an active UPS capacity estimation algorithm based on the PV power generation. It is designed in a structure that can be expanded to power trade afterward. The load usage fluctuates according to the year, month, and day. At this time, the power capacity that can respond also varies. t is difficult for users to estimate the ESS capacity for economical operation every time. Therefore, user convenience was considered by designating a new set value compared to the current value by calculating the accumulated value based on the EMS data in the system.n addition, the capacity calculation takes into account the economic profit obtained from power generation only from the current PV power generation, the economic profit through the ESS, and the economic profit obtained when the DR request comes.Then, a method of prioritizing revenue and redistributing capacity according to priorities was adopted.

3. Result and analysis

3.1 *Intelligent UPS algorithm simulation*

Figure 6 shows the experimental results using PISM. The load was calculated by considering only the main load of the UPS line in consideration of the load characteristics of the application site. PV generated artificial power drop for algorithm verification and verified whether the algorithm was applied.As can be seen from the waveform, the available capacity of the UPS is changed by actively calculating the available capacity according to the PV power generation by the applied algorithm.Then, it can be seen that the SOC fluctuates according to the inverter output.

Figure 7 shows the hardware and software configuration for the experiment. Experiments were performed based on simulation. For the proposed system configuration, the distribution board was designed and manufactured by separating the DC and AC lines of the distributed power supply and the load side, and experiments were conducted through EMS design.

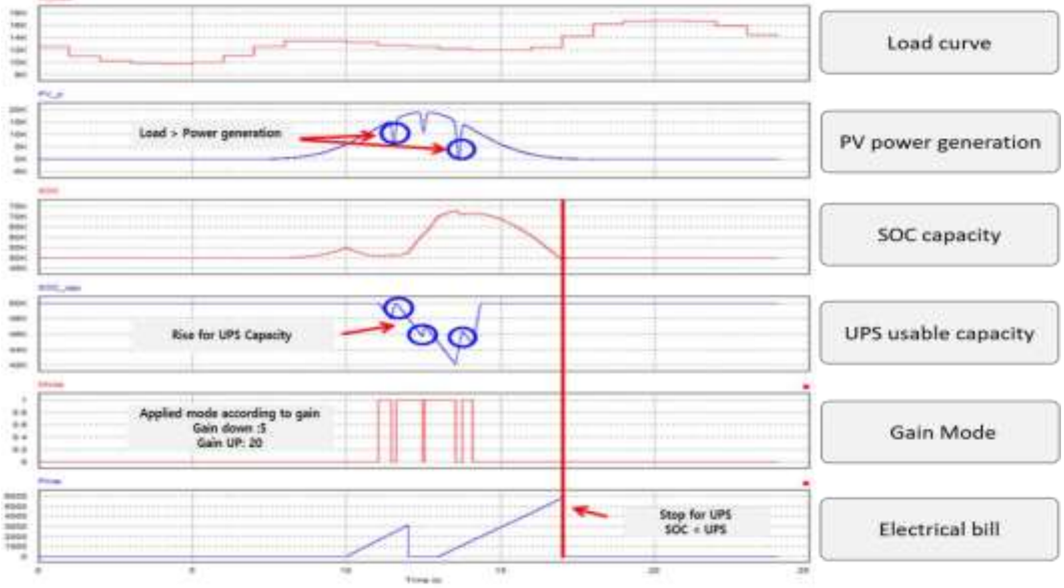


Figure 6. Simulation results applying intelligent UPS algorithm

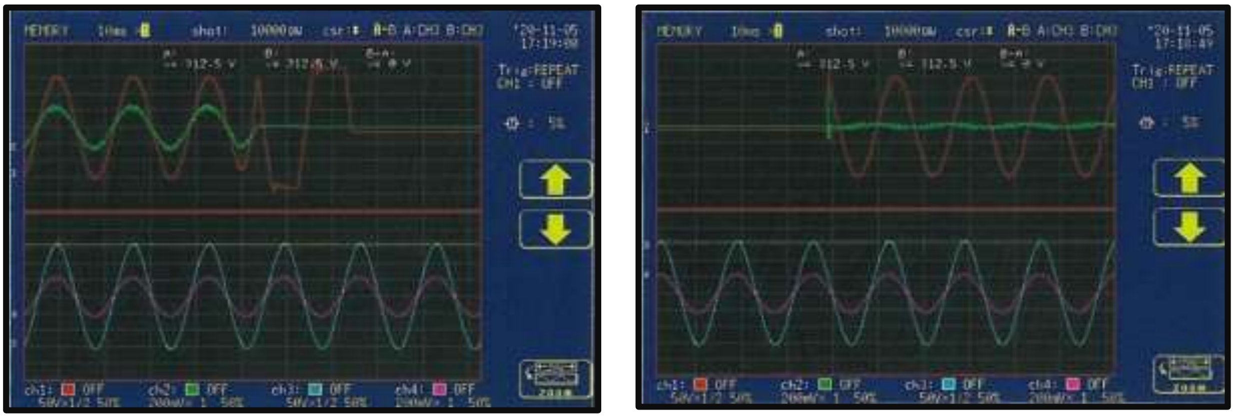
(a) **(b)**

Figure 7. Experimental configuration of intelligent UPS system (a) Hardware (b)software

3.2 *UPS Performance Verification*

Figure 8 shows the inverter operation characteristics of the UPS.For uninterrupted changeover, it was confirmed that the inverter was supplied stably through uninterrupted transfer even in case of an accident and during restoration.As a result, the transfer was made without permission.Also, when the system was restored, it was confirmed that it was operated without succession at 0ms.The upper graph shows the grid voltage and current, and the lower graph shows the grid voltage and current supplied to the load.When the grid voltage is cut off, it can be confirmed that the voltage supplied to the load is switched without interruption, and when the grid voltage is restored, it can be confirmed that the voltage supplied to the load is supplied without interruption.

Figure 9 shows the resulting waveform according to the system control.In Fig. 9(a), it can be seen that the slope in section ①, where the inverter output rises compared to the PV power generation, is gentle, and in the section ②, where the inverter output decreases compared to the PV power generation, the slope decreases sharply. When the SOC minimum value is reached by the proposed algorithm, the output of Inverter 1 and Inverter 2 rises again at the point when the output of Inverter 2 increases, and it can be confirmed that the SOC value for the UPS is secured. In Fig. 9(b), it can be seen that the SOC fluctuation when the load fluctuation is gentle and showing a clear difference from the PV output amount changes more gently than in Fig. 9(a). In order to secure the SOC for the UPS, by modifying the gain of the algorithm, the slope of the rising and falling curves was adjusted to increase the battery utilization rate of the UPS.



(a) (b)

Figure 8. Waveform of UPS system startup experiment
(a) cut off grid voltage, (b)grid voltage restoration

(a) (b)

Figure 9. UPS capacity change result waveform

4. Conclusion

In this paper, a UPS that can operate at all times by linking distributed power is proposed.Through the algorithm proposed to the UPS, which is used only in case of an accident, the UPS's energy utilization rate was increased and the stable function was performed by configuring a system that can be used on a regular basis while performing the functions of the UPS.If the system proposed in this paper is distributed, it is expected that it can play a large role in the utilization of distributed resources.

5.Acknowledge

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