Demonstrative Research Project to Stabilize Output of Hybrid PV Power Generation Systems (PV + MH + Capacitors)

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Abstract

As an energy source that is eco-friendly, many Photovoltaic (PV) power generation systems are being adopted. Recently, New Energy and Industrial Technology Development Organization (NEDO) carried out the "Demonstrative Research Project to Stabilize Output of Hybrid PV Power Generation Systems (PV + MH + Capacitors)" in cooperation with the countries that have areas where the sunlight and the amount of water flow in rivers change greatly between rainy and dry seasons. As a member of this project, the company developed and manufactured major equipment and facilities for this demonstrative research.

In this project, we developed the "control techniques to relieve output variations in PV generation to minimize adverse influence upon power quality" with the use of electric double layer capacitors.

1 Preface

Recently, the amount of Photovoltaic (PV) power generation systems has been increasing as eco-friendly an energy resource. In supporting the power in the areas where electricity access is still limited, construction of small-scale local microgrid is expected to increase. In such a case, the PV power system and Micro-Hydropower (Micro-Hydro or MH) are the most suitable technologies to use because it does not require the installation of any large-scale power transmission line or supply bases for fossil fuels.

The hybrid system that comes in combination with PV power and Micro-Hydro is considered to provide advantages such that power outputs can be compensated by each other sources in areas where sunlight and river water volume change greatly between rainy and dry seasons. This is because the amount of water in the river increases in rainy season when the PV output decreases as a result of decrease in sunlight and it is possible to increase the Micro-Hydro output. On the contrary, in dry season when river water decreases, sunlight increases and the PV power output becomes high.

However, there is a challenge: PV power is subject to changes in output caused by change in the sunlight volume, and output control by Micro-Hydro results in slow follow-up to variation in power demand. In order to solve this technical problem, New Energy and Industrial Technology Development Organization (NEDO) started in Fiscal 2007 International Cooperative Demonstration Project Utilizing PV Power Generation Systems by the name of "Demonstrative Research Project to Stabilize Output of Hybrid PV Power Generation Systems" in cooperation with the Government of the Lao People's Democratic Republic. In this project, after building the facilities, from April to September 2010 a series of verification tests was carried out. (Main contractor of Contract Research: The Okinawa Electric Power Company, Incorporated / Sub-contractor: Okinawa Enetech Co., Inc. and Meidensha Corporation)[(1)(2)(3)] As a member of this demonstrative research project, we developed various systems needed for this research project and performed verification tests.

This paper introduces the results of verification tests on multiple control methods applying Electric Double Layer Capacitors (EDLC) for alleviating frequency deviations. The output characteristics of EDLC observed during a long-time operation are also introduced.

2 Demonstration System and EDLC Control

Fig. 1 shows configuration of the system developed for this demonstrative research. We had been in charge of production of equipment indicated in the dashed-line box. The Micro-Hydro of 110kW, 400V, and 50Hz functions as the main power supply (voltage source) that is interconnected with a 40kW PV. The generated power is stepped up to 22kV by a transformer and distributed to various areas through the transmission lines with the total length of approximately 20km. The DC circuit of PV Power Conditioning Subsystem (PCS) units is connected with the EDLC (capacity: ±40kW × 30 seconds) through the DC/DC converter in order to relieve frequency deviations. There is a load resistor that can consume a maximum of 75kW, adjustable in 5kW steps. In addition, there is weather observation equipment to collect meteorological data and the data logger to record data of verification testing.

Fig. 2 shows the control block of EDLC applied to this system. As the measures taken to relieve frequency deviations, there are three control methods available: ΔP control that regulates the PV output variation below the preset changing rate, Δf control that generates active power output in order to cancel frequency deviations, and ΔP + Δf control that is a combination of the above two.

The State of Charge (SOC) control was also performed. This control method is used to regulate the state of EDLC charge toward the goal level within the range where the frequency is never influenced.

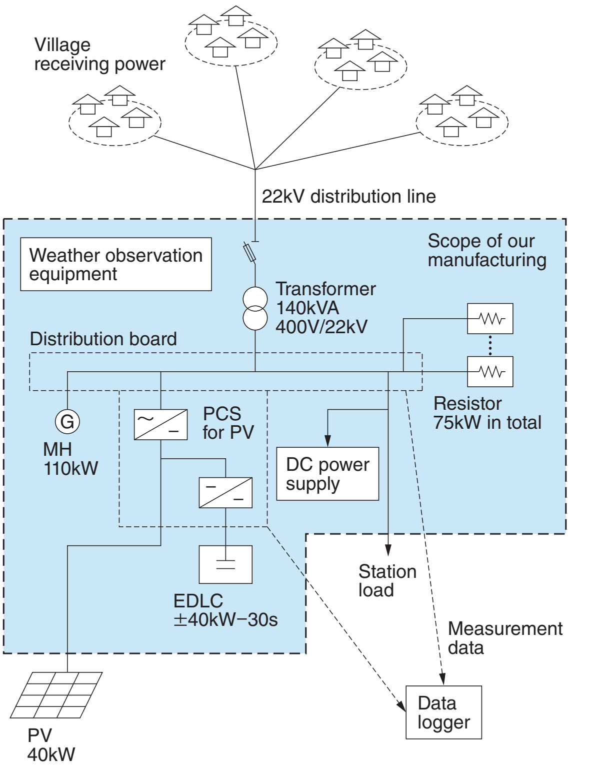

Fig. 1 System Configuration

Illustrates the configuration of the system to be developed for the demonstrative project.

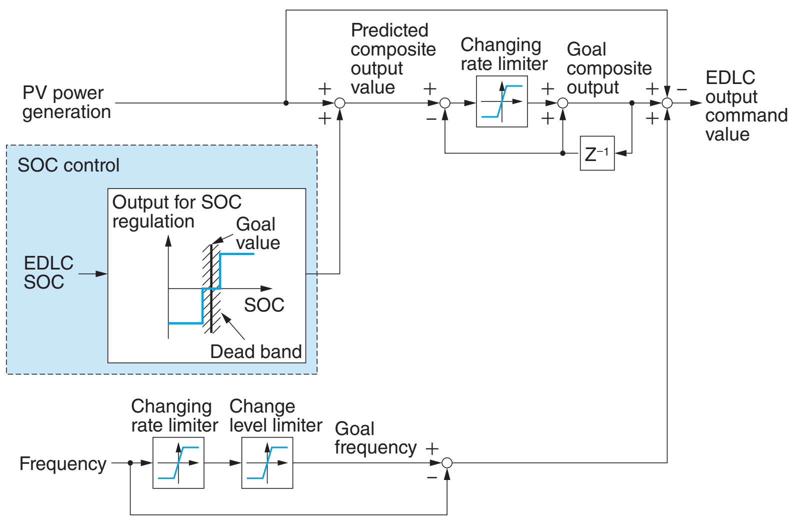

Fig. 2 EDLC Control Block

There are three control methods available: ΔP control that regulates the PV output variation below the preset changing rate, the combined control of Δf that generates active power output in order to cancel frequency deviations, and SOC control of EDLC.

3 Result of Evaluation Test

3.1 Comparison of Frequency Deviation Compensation Response Characteristics by EDLC Control

Fig. 3 shows changes in EDLC and Micro-Hydro outputs and frequency with time when the DC incoming Molded Case Circuit-Breaker (MCCB) from PV array to PCS was artificially switched off at time 0 in order to cause a sudden reduction of PV output having a capacity of approximately 30kW. **Fig. 3 (a)** shows the EDLC output obtained under ΔP control, and **Fig. 3 (b)** shows the EDLC output under ΔP + Δf control. In regard to the control constant (output changing rate) of EDLC, the optimal values indicated in Reference (2) are adopted (0.7kW/s for ΔP control and 1.0kW/s for ΔP + Δf control). The data used in this case are the 0.1s mean values calculated from instantaneous values of voltage and current

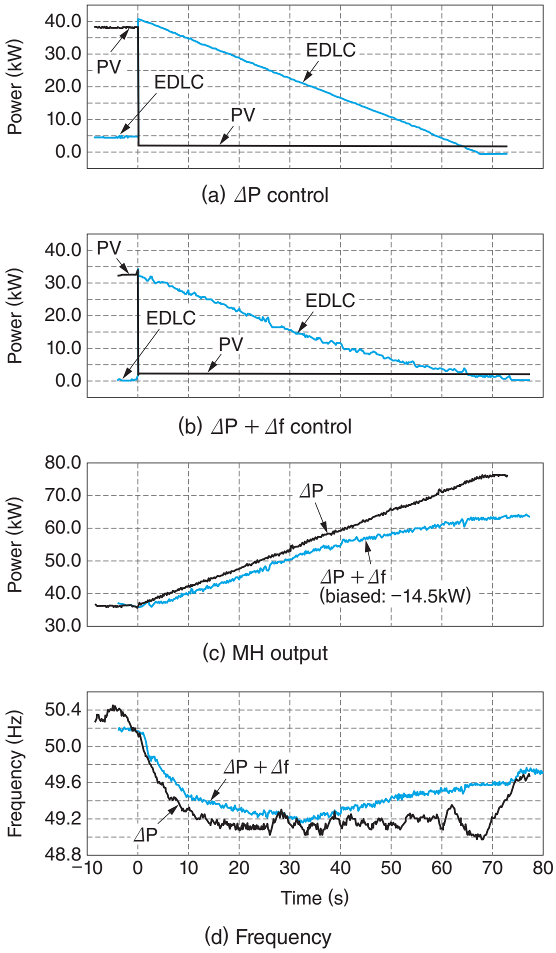

Fig. 3 **EDLC and Micro-Hydro Output and Frequency Deviation Waveforms upon Sudden Decrease in PV Output**

Changes in EDLC and MH outputs and frequency with time are shown, observed when a sudden reduction of PV output is artificially caused under ⊿P control and ⊿P + ⊿f control.

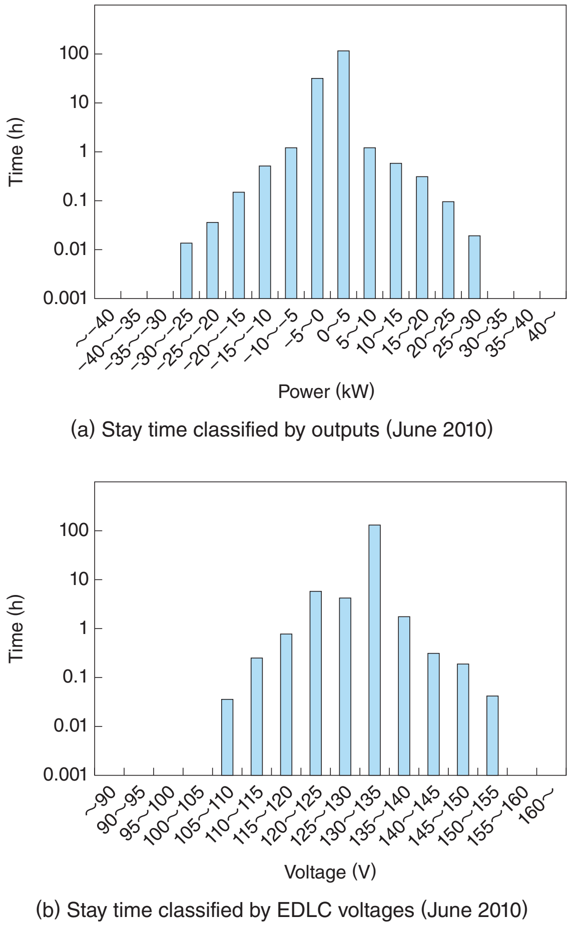

Fig. 4 **Distribution of Stay Time Classified by EDLC Outputs and Voltages**

Distribution of stay time is shown, classified by EDLC outputs and voltages. Diagram (a) shows distribution classified by outputs and Diagram (b) shows distribution classified by voltages.

recorded by 0.1ms sampling.

When the behavior of EDLC output is compared, there is a linear decrease in output under ⊿P control while the gradient of decrement slowly becomes moderate as the output decreases under ⊿P + ⊿f control. As a result, as shown in **Fig. 3 (c)**, an increase in MH load becomes somewhat greater under ⊿P control and reduction of frequency also becomes greater (**Fig. 3 (d)**). While the EDLC output is being reduced, the frequency is almost kept constant. Under ⊿P + ⊿f control, on the other hand, recovery of frequency begins somewhat earlier. In addition, fine frequency deviation is also suppressed.

In order to relieve frequency deviation attributable to load changes, it can be said that the use of ⊿P + ⊿f control is most effective although the amount of energy needed for the EDLC becomes somewhat larger. If the ⊿f control only is used, there can be a subject to remain such that responses tend to be somewhat delayed at a stage where the frequency begins to lower shortly after the occurrence of variations in PV output.

3.2 EDLC Output Characteristics after a Long Time of Operation

In order to grasp the EDLC output characteristics after a long time of operation, we evaluated the stay time for each span of EDLC output and voltage. Meanwhile, during the period of artificial PV ON-OFF actions performed by the project research members dispatched to the project site, the EDLC has tended to work against variations far greater than actual PV output variations. In this paper, we cover one month in June 2010 when there was no artificial output operation. ⊿P control was adopted for the EDLC control system.

Fig. 4 (a) shows the stay time of the respective output modes. In June 2010, the operation of charge-discharge was carried out within the range of 30kW at the maximum against natural PV output variations. At that time, nearly 90% of output conditions were kept within 5kW of charge-discharge. The result was the same in August 2010 when no artificial testing was carried out by project research members.

Fig. 4 (b) shows the stay time of the EDLC voltage levels. Since the EDLC characteristically tries to maintain 133V if there is no variation in PV output, the stay rate of 130 ~ 135V occupies more than 98% of all. The voltage distribution is kept within the range of 105 ~ 155V and this implies that approximately 75% of energy was used within the range of 90 ~ 160V where the EDLC can maintain its operation.

Although both output and voltage have some margins in regard to their design values, there can be some possibility of no occurrence of the most rigorous condition because the evaluation period is short. In addition, reduction of EDLC capacity is also anticipated due to aged deterioration. Given the aforementioned, the design for this project is considered largely appropriate.

4 Postscript

In the Lao People's Democratic Republic, we constructed the stand-alone hybrid power supply demonstrative facilities using PV, Micro-Hydro, and EDLC. For the major purpose of relieving frequency deviations, we made data acquisition and comparison from the demonstration test by multiple EDLC control methods. For system management after the completion of demonstration test, we decided to use the method of ⊿P + ⊿f control because this type of control can provide well balanced reactions to PV output variations and load changes. As a result of EDLC output characteristics, we confirmed that our facility design for this demonstrative research was fairly appropriate.

We expect that by the result of this demonstrative research, it will become one of the eco-friendly power supply systems contributing to solving the no electricity access areas.

《References》

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