Priority Subjects with Limited Terms — **Development of a Supply/Demand Infrastructure for Next-Generation Electric Power**

Assessment of System Security Assuming High Penetration of Photovoltaics

Background and Objective

As renewable energies spread, particularly photovoltaics (PV), it is important to ensure power system stability (rotor angle stability, frequency stability and voltage stability) following the occurrence of transmission system faults.
However, the effects of transmission system faults on power systems in the event of widespread PV penetration have not yet been fully investigated. It is important to clarify the effects and develop countermeasures to ensure power system stability in the future.

The purposes of this project are:
(1) To evaluate the effects of power system faults on the transmission system
(2) To conduct experiments and identify the characteristics of a Power Conditioning System (PCS) structured from an inverter of PV with anti-islanding protection
(3) To establish numerical PV models for time-domain simulation
(4) To develop countermeasures for ensuring power system stability in the future

Main results

1 Improved Convenience of PV Models for Simulation Analysis

Physical tests to identify the characteristics of PCS for residential PV in CRIEPI's Power System Simulator have shown that when the PCS is temporarily suspended after a transmission system disturbance, not only the control system of the inverter, but also the automatic islanding detection relay, is greatly affected.

Therefore, PV simulation models with an automatic islanding detection relay for the CPAT*1 simulation analysis have been developed. In order to efficiently evaluate the effects of high PV penetration on system security, three typical PCS models for residential PV were combined into one as the standard model for CPAT (Table 1), to improve the convenience of CPAT users.

2 Experimental Extraction of Conditions for Generating Reactive Power Oscillation of the PCS by the Response of the Active Islanding Detection Method

In some tests using CRIEPI's Power System Simulator, periodic reactive power oscillation (period 0.1 second) has been observed. This oscillation is due to the response of the active islanding detection method of PCS*2 for PV.
To investigate the conditions under which this phenomenon occurs, resistance loads and the PCS for PV are connected at the end of the test system (Fig. 1). Experiments are then carried out with the opening and closing of the resistance load as a system disturbance, while varying the capacity of the PV and transmission line length of simulated 275 kV and 66 kV as parameters. The results show that this phenomenon is likely to occur under conditions in which the terminal voltage of the load is likely to fluctuate when the PV capacity is large*3 and the transmission line length is long (Fig. 2).
In the future, the detailed conditions under which this phenomenon occurs and the probability of occurrence in an actual power system will be studied.

3 Evaluation of the Fundamental Effects of Transmission System Faults on Power Systems with High PV Penetration and Wind Power Generation

Numerical simulations using CPAT were carried out for various full-scale power system models (Fig. 3) in order to evaluate the impact on the system stability in the case of high PV penetration and wind power generation (WP). The results show that the effects on the power system stability vary depending on the capacity and the position at which renewable energy power generation is introduced, and also on load flow and system fault conditions. Because these influences are largely dependent on the characteristics of the individual power system, additional analysis on the standard power system model will be performed in order to summarize the effects on power system stability, including the relationship with the power system characteristics.

*1 CPAT (CRIEPI's Power system Analysis Tools) was developed by CRIEPI. In this study, a transient stability analysis tool of CPAT was used. CPAT is used by all 10 electric utilities in Japan.
*2 PCS for residential PV with a new islanding detection relay named AICOT (Anti-Islanding COntrol Technology) in CRIEPI's Power System Simulator
*3 The oscillation phenomenon occurs when the short-circuit capacity ratio (short-circuit capacity of the terminal to which the load is connected) is smaller than a certain value. The threshold is presumed to differ depending on the type and manufacturer of the PCS. It is also possible that factors other than short-circuit capacity ratio are involved in the phenomenon.

Table 1: Standard PCS model for residential PV in CPAT (3 kinds of automatic islanding detection relay are available)

Model #1	Active System: The AICOT(Anti-Islanding COntrol Technology) Passive System: System to detect Changing Rate of Frequency
Model #2	Active System: Frequency Shift System Passive System: System to detect Jumping Voltage Phase
Model #3	Active System: Variable Reactive Power System Passive System: System to detect Jumping Voltage Phase

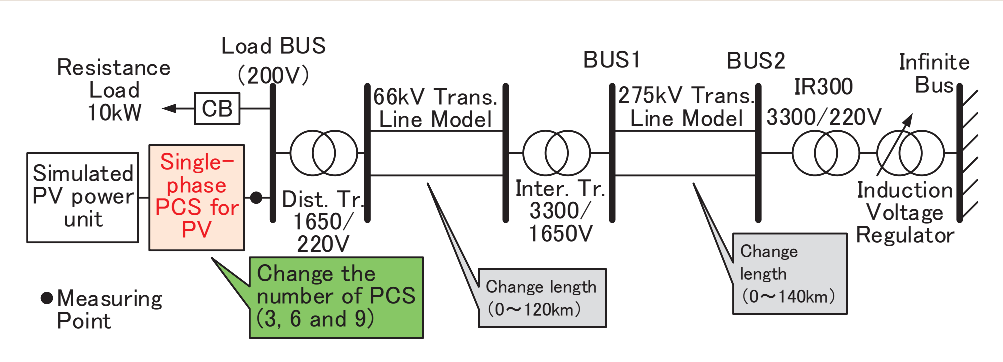

Fig. 1: Test system in CRIEPI's Power System Simulator (Experiments with the opening and closing of resistance load)

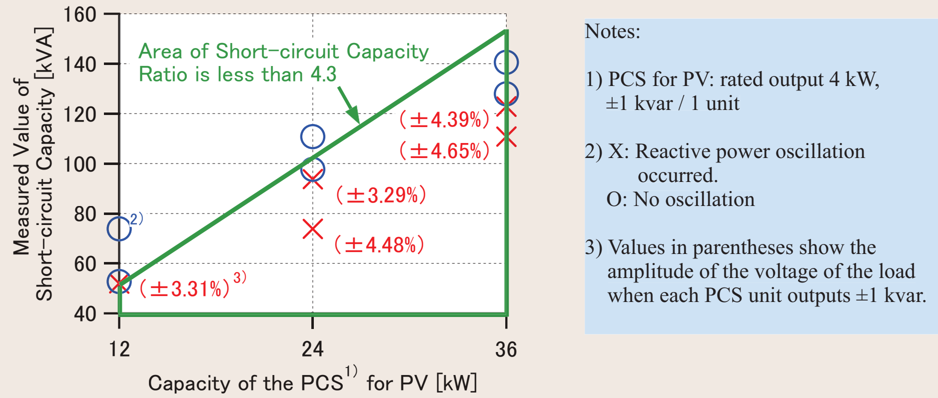

Fig. 2: Test conditions under which reactive power oscillation occurred in CRIEPI's Power System Simulator

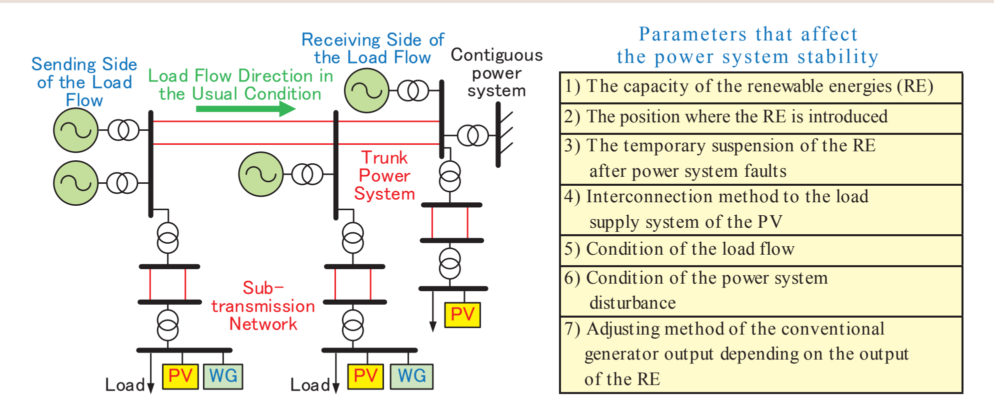

Fig. 3: Parameters that affect power system stability and image of a large-scale power system