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

Development of a Next-Generation Coordination System for Power Demand and Supply

Background and Objective

Expectations towards renewable energy sources (RES) such as photovoltaic (PV) power generation are intensifying and it is predicted they will penetrate the utility system in high volume. As such, it is necessary to develop techniques to achieve both effective use of RES and preservation of power quality, safety and stability of utility systems at a low cost. The objective of our research are to establish basic techniques for distribution systems such as restraint of voltage rise, protective cooperation and so on, and to develop coordination system techniques for power demand and supply including a technique for the effective use of distributed power generation.

Main results

1 Development of an islanding prevention method in case of secondary transmission system faults

The establishment of a method to prevent islanding (Fig. 1) is necessary. Islanding may occur on a wide scale in the case of upper secondary transmission system (66kV) faults upon high PV penetration. Islanding detection characteristics have been clarified through the experiments and simulation analysis using a typical distribution system model in 2012 (R12020). In 2013, more detailed characteristics were clarified through experiments and simulation analysis* assuming several operation forms of distribution systems (system configuration, operation method in fault, grounding method etc). These included ungrounded distribution system with distribution towers as well as different locations and opening times of circuit breakers at fault occurence. The results led to the following findings. Islanding detection time tends to decrease more for ungrounded distribution systems compared with resistance grounded system and increase when the faults are cleared by operating ground over voltage relay (OVG, B in Fig. 1) at the same time as a circuit breaker (A in Fig. 1) of a transmission line is opened. The opening time of the circuit breaker of transmission line has little influence on the islanding detection time after the breaker opened (Table 1) (R13025). Based on these results, we plan to investigate facility and operation forms of the utility and measures in the facility/operation for preventing islanding responding to penetration of distributed power generation.

2 Development of 3-phase imbalance correction method for distribution lins

Voltage management of high voltage distribution lines may become difficult due to the increase of 3-phase imbalance by penetration of large capacity single-phase appliances such as heat pump type water heaters in addition to PV systems. A voltage imbalance correction method that controls each phase voltage independently using STATCOM is proposed, and its effectiveness has been validated through simulation analysis. The results show that the proposed method suppresses the increase of voltage imbalance caused by increased penetration of PV (Fig. 2(a)), and decreases the number of locations where the voltage exceeds the regulated amount as well as shortens the duration of voltage deviation with the penetration ratio above 40% (Fig. 2(b)) (R13024).

3 Development of a new reactive power control method according to the change rate of PV output

When the volume of PV systems installed in a distribution system increases, the required capacity of fast-response and high-cost voltage control equipment (SVC) may increase in order to suppress voltage fluctuation. To reduce the required capacity of SVC by supplementing SVR operation, a reactive power control method of power conditioning subsystem (PCS) responding to the change rate of PV output was proposed (R12012). Because the proposed method is expected to supplement Load Ratio control Transformer (LRT), the effectiveness is evaluated by simulation analyses. Results indicate that the proposed method is able to complement LRT operation, and the required capacity of SVC is further reduced by supplementing both SVR and LRT (Fig. 3) (R13019). Meanwhile, the constant power factor control is also effective to reduce SVC capacity, but the proposed method has the advantages of smaller distribution line loss compared to that of the constant power factor control.

* Experiments were conducted at Akagi Testing Center using ADAPS (Autonomous Demand Area Power System) Demonstration Test Facility. Simulation analysis used instantaneous value analysis program called Xtap developed by CRIEPI.

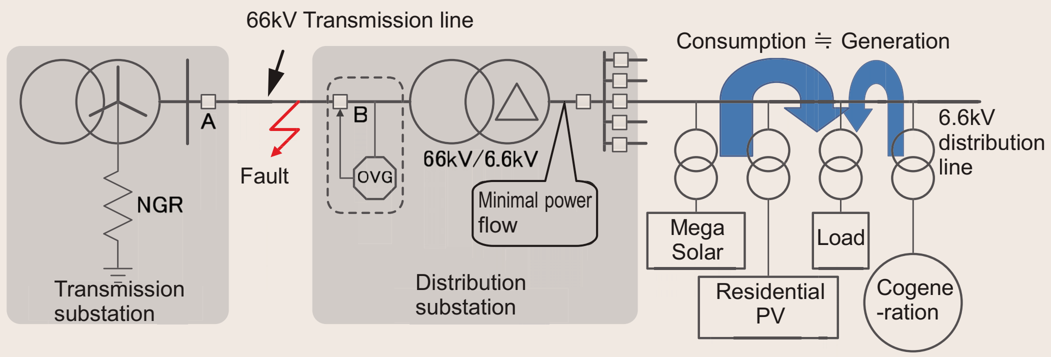


Fig. 1: Condition of the power system below the transmission transformer at islanding

Islanding may occur across a wide area including several 6.6 kV distribution lines when the electrical load and generated power of distributed generators are balanced after opening the circuit breaker at A, or simultaneously opening both at A and B after a 66 kV transmission line fault has occurred.

Table 1: Influence of differing system configurations and operations on the fault condition to islanding detection time (Simulation results)

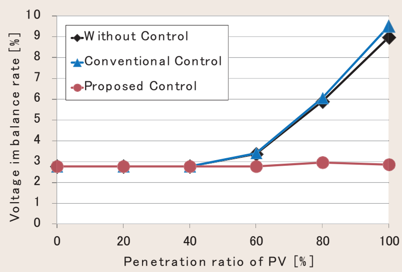
Results with a single-line grounding fault in a 22 kV system where a synchronous generator (2MW) and PCS (600kW, equipping new type active islanding detection function) for PV use are parallel operated. Islanding detection time tends to increase when the faults are cleared at the same time as a circuit breaker of transmission line is opened regardless of the grounding method, and is not influenced by the opening time of a circuit breaker in the transmission line from fault occurrence. Furthermore, islanding can be swiftly detected in the case of an ungrounded system when the faults remain.

(a) Resistance grounded system

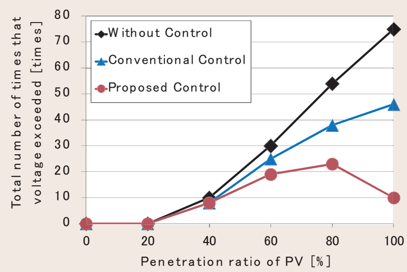
Neutral grounding method: 200A grounding resistance		Opening time of transmission line's circuit breaker [sec]		
		0.5	1.0	2.0
Islanding duration [sec]	Case of fault uncleared	0.856	0.856	0.856
	Case of fault cleared (Opening breaker at A and B simultaneously)	more than 3	more than 3	more than 3

(b) Ungrounded system

Neutral grounding method: Ungrounded (distribution tower)		Opening time of transmission line's circuit breaker [sec]		
		0.5	1.0	2.0
Islanding duration [sec]	Case of fault remained	0.327	0.326	0.327
	Case of fault cleared (Opening breaker at A and B simultaneously)	more than 3	more than 3	more than 3



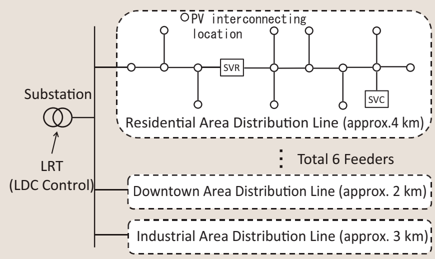
(a) Voltage imbalance rate



(b) Daily voltage exceeding times*2

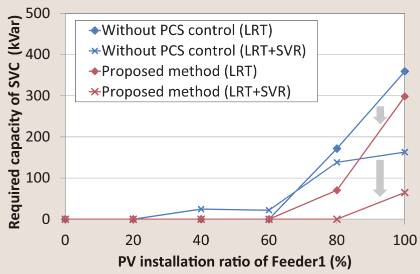
Fig. 2: Comparison between conventional and proposed method with each PV penetration ratio*1

*1 PV penetration ratio = Total capacity of installed PV/distribution line capacity.
*2 n1+n2+ ---+ni+ -- +n24, where ni is the number of locations where distribution line voltage exceeds upper limit in 1 hour of i hour



(a) Distribution system model for simulation

A distribution bunk model consists of 6 feeders (residential area, downtown area, industrial area). PV systems are installed in all feeders.



(b) Effect of SVC required capacity reduction (complementing LRT and SVR)

Shows relationships between required capacity of SVC and PV installation ratio of a residential area distribution feeder.

Fig. 3: Effect of the proposed method on SVC capacity reduction