Study Committee B5

Protection & Automation

Paper ID_10611

Experimental validation of emergency frequency control by considering the self-disconnection characteristics of renewable energy sources to enhance the resilience and decarbonization aspects of power systems

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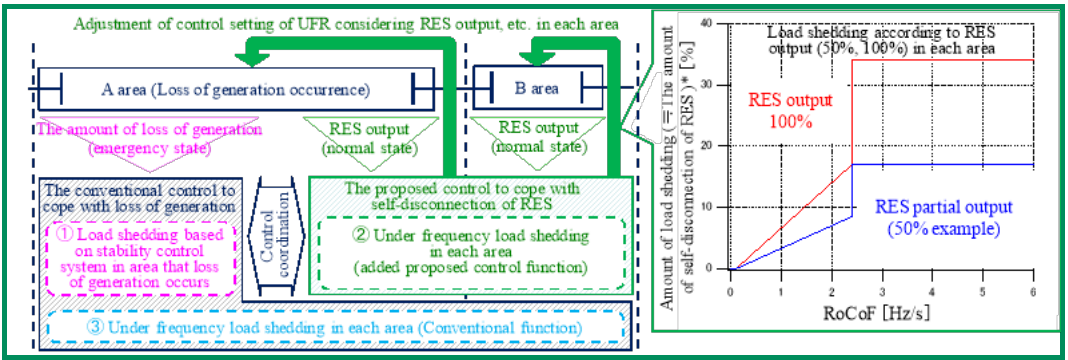
Introduction and Motivation

- In recent years, **RES self-disconnection following the loss of large-scale generation, characterized primarily by anti-islanding protection relay**, has caused frequency stability deterioration.
- Further increases in RESs could decrease system inertia, eventually increasing the RoCoF following the loss of generation, causing significant **large-scale self-disconnection of RESs** and **the risk of large-scale power outages** due to frequency drops.
- In the case of the large-scale self-disconnection of RESs or the loss of generation exceeding the scale of contingencies, **under-frequency load shedding (UFLS) schemes** as a backup become important to ensuring frequency stability. In Japan, **the RoCoF relays** are expected to contribute to **faster load shedding** as one of the countermeasures for enhancing UFLS.
- Therefore, the authors have developed a **new control method using the RoCoF relay** that can flexibly and quickly respond to events in which frequency stability is deteriorated owing to RES self-disconnection following the loss of large-scale generation.

Method/Approach

- In Japan, the idea of **adjusting the control settings of UFLS using information and communication technology** effectively according to the system status has been proposed as a new approach for enhancing UFLS in future systems. However, no concrete measures have been proposed to date.
- Therefore, based on this approach, the authors proposed a **new load shedding scheme using improved UFLS as a decentralized control scheme**.
  - In the proposed control method, **a load shedding function based on RoCoF considering the characteristics of the anti-islanding protection relay of RESs** is added to UFLS.
  - Furthermore, **the amount of load shedding is adjusted by changing the RoCoF relay settings** in real-time according to the RES output, estimated self-disconnection, etc. Adjustment of the relay setting is conducted in the following flow.
    1) Estimate the output of RESs.
    2) Estimate **the amount of RES self-disconnection (≒load shedding) vs. RoCoF**.
    3) Adjust the settings of each RoCoF relay (use or non-use, threshold level, and time delay as necessary).
    4) Send setting change command to each RoCoF relay.



- Suppose large-scale generation loss occurs in an area and RES self-disconnection in each area following frequency drops. In that case, load shedding is realized **against the generation loss and RES self-disconnection in the area** where generation loss occurs. In other areas, load shedding is conducted **against RES self-disconnection**.

⇒ In this manner, **even in the case of RES self-disconnection**, which would be difficult to recover the frequency with only conventional control schemes, **the proposed control method can recover the frequency back to acceptable levels**.

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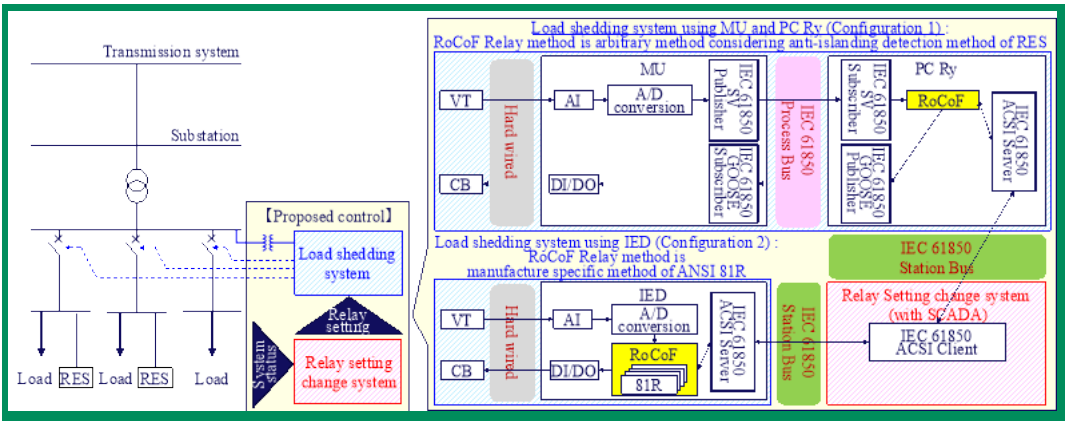
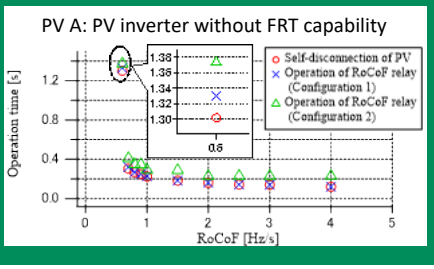
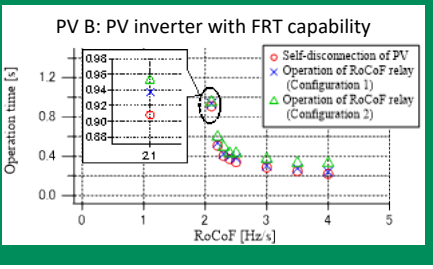
Configuration of Proposed Control System

- In the proposed control method, it is necessary to **change the RoCoF relay settings in an appropriate cycle** (on the order of minutes) to adjust the amount of load shedding appropriately in real-time according to the RES outputs. It is important to **avoid requiring a large amount of information to change the control settings**.
- Therefore, **applying** the proposed control scheme is preferable **not to the entire grid but rather to a certain scale or unit, such as a distribution substation**.
- **Two systems** are needed in each substation to apply the proposed control method to distribution substations.
  - A "**load shedding system**" using the RoCoF relays considering the characteristics of the RES anti-islanding protection relay.
  - A "**relay setting control system**" to adjust the amount of load shedding appropriately according to the system status.
  - Note: It is considered that the system can be constructed at **a lower cost and with higher scalability** than before **by using a configuration compliant with IEC 61850**, which is being introduced in monitoring control systems and protection relay systems.



- A load-shedding system consists of followings.
  - Configuration 1 : a MU compliant with IEC 61850 and the RoCoF relay using a PC (the operating system was Linux).
  - Configuration 2: an IED compliant with IEC 61850, including ANSI 81R protection relays.
- The self-disconnection characteristics of the RESs due to the anti-islanding protection are accurately emulated using the PC and 81R elements in Configurations 1 and 2, respectively. Both Configurations 1 and 2 could accurately and quickly discriminate between the presence and absence of PV self-disconnection for ramp-like frequency fluctuations.





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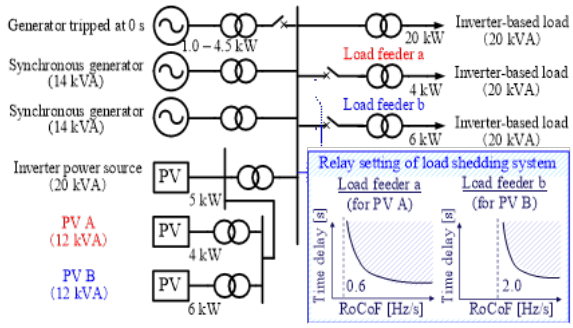
Experimental Validation of Proposed Control System

- The capability of the proposed system in **an actual power system** was validated through laboratory tests **assuming the loss of large-scale generation in the power system simulator**.
- Both Configurations 1 and 2 of the proposed load shedding system can realize **accurate and prompt load shedding for complex and diverse frequency fluctuations** at each generation loss scale, even in the case of actual measurement data including noise.

Test System

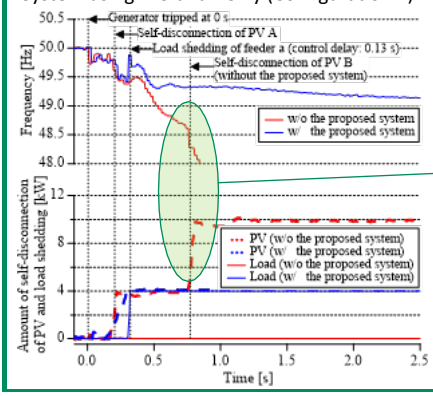


<Operating conditions>

- The load demand was approximately 30 kW.
- The power-frequency constant was set to approximately 8%.
- The ratio of the inverter output to the load demand was approximately 50%.

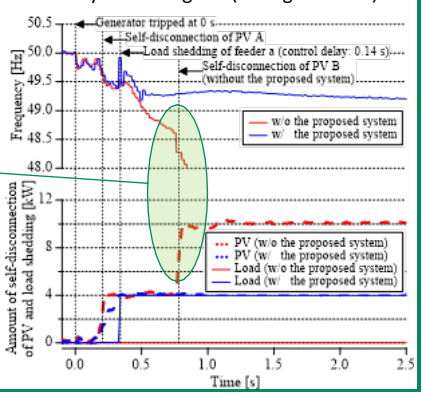
Test Result

System using MU and PC Ry (Configuration 1)



The proposed control method can help **avoid cascading RES self-disconnection** and **enhance the frequency stability** following generation loss.

System using IED (Configuration 2)



Conclusion and Future Work

- A proposed and constructed load shedding system exhibits **noise immunity** and can **perform accurate high-speed load shedding**, thereby **enhancing the resilience of future power systems** with large-scale RESs.
- The main future work is to **establish a method to adjust the amount of load shedding by changing the RoCoF relay setting** using IEC 61850 according to the system status.