

## **A Study on Black Start Procedures at Kyushu Electric Power**

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### **Abstract**

Kyushu Electric's service area has never experienced blackouts. However, to prepare for this possibility, the company has begun to develop an original system for black start procedures if a blackout occurs. Currently planned procedural steps to recover a power system are as follows:

- 1) Synchronize multiple hydropower generators, and apply voltage to the power system's transformers and transmission lines to send electric power to thermal power plants;
- 2) Send electric power to a part of the load;
- 3) Start up thermal power generators, and synchronize them with the power system; and
- 4) Increase the generators' output and send electric power to the load extended in the power system.

Recovery employing such a small-scale hydropower generation system may lead to several problems, such as frequency instability and equipment damage arising from abnormal voltage. This paper describes countermeasures for the major problems associated with 1) and 2) above, as well as issues under examination for resolving problems associated with 3) and 4).

- *Countermeasures against abnormal voltage when applying voltage to transformers:* The results of a computer simulation as well as a field test found that a transformer's voltage increases after applying voltage to it. This is because the saturation-unsaturation repetition in the iron core of the transformer causes voltage to oscillate. The smaller the hydropower generator is, the larger the amplitude of voltage oscillation. Two effective countermeasures were derived from a computer simulation. Abnormal voltage can be eliminated by increasing the capacity of the generator to twice that of the transformer's capacity to which voltage is applied, and applying low voltage under 0.9PU to the transformer.

- *Hydropower generator modeling for evaluating frequency stability:* When a disturbance occurs in a small-scale hydropower generation system, a computer simulation judges whether the system can be operated in a stable manner. However, a conventional generator model was made for a normal, large-scale system with less fluctuation in the turbine's revolution. Given this situation, a more accurate generator model exclusive for a small-scale hydropower generation system was newly created, with a focus on the torque characteristics of the turbine. The torque characteristics act to stabilize the system, allowing the creation of an affordable margin. Proper review of the recovery procedures is made possible.

Incorporating these practices contributes to the actualization of procedural steps 1) and 2). Further study on the development of Kyushu Electric's original black start procedures will continue.