Analysis of Possibility of Replacing Self-starting Generator with BESS

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Abstract. Recently, Many papers have been published on other's utility of the existing BESS (Battery Energy Storage System) equipment that stabilizing the output of the renewable energy and adjusting the frequency of the power system. In 2013, the EPRI has reported a study of the primary power plant starting using BESS for the replacement of two black start generators of American Electric Power (AEP) that will be torn down. As the social interest in the power outage has increased since wide-area blackout in South Korea in 2011 it is time to research not only a reliability of the power restoration plan but also reducing power restoration time. In case of wide area black-out, the primary transmission line should be energized at first after opening all circuit breaker in power system. Since these transmission lines are long-distance and no-load, various problems may befall in the process of energizing. In this paper, the restoration process using BESS for primary transmission line was analyzed. PSCAD / EMTDC was used for simulation.

Introduction

Recently many papers have been reported on various application, in addition to the existing BESS(Battery Energy Storage System) equipment that stabilizing the output of the renewable energy and adjusting the frequency of the power system[1-6]. In 2013, the US EPRI has reported a study of the primary power plant starting using BESS for the replacement of two black start generators of American Electric Power(AEP) that will be demolished[7]. Siemens also supplied BESS with a capacity of 2.85[MW] / 720[KWh] for the Black Start of the German gas turbine power plant. However the report was not published. Since BESS can operate at high speeds and there is no limit on the installation site, it is expected that if it can replace the self-starting generator, it can reduce the current transmission line which is composed of long distance. In addition, it is expected that it will be possible to shorten the restoration time. Currently, the Korean power system is operating near the stability limit due to the continuous load increase, so that the possibility of large scale power outage is increasing. In 2011, a blackout occurred in each region in Korea to prevent the frequency drop due to reserve power lack. After this in Korea, as the social interest in the power outage has increased since wide-area blackout. Therefore it is time to research shortening the power restoration time as well as reliability of the power restoration plan.

In the case of a total blackout or wide-area blackout, other countries' initial countermeasure have adopted method of entire power system restoration which sequentially restores outage area by opening entire power system and energizing prime power supply system. Korea adopts the same method. However, this method can cause various problems such as the Ferranti effect [8], since the long-distance no-load transmission line is energized in restoration process. In this paper, the restoration process using BESS for primary transmission line was analyzed. PSCAD / EMTDC was used for simulation.

Case Study

The Korean primary transmission systems are divided into seven regions. GyeongIn Northern area
primary transmission lines were examined in this paper. Figure 1 shows the primary transmission lines in GyeongIn Northern.

The self-starting generator in GyeongIn Northern primary transmission line is ChunCheon Hydro Plant#1 and the primary power plant is PoCheon Combined Cycle Power Plant#1.

PoCheon Combined Cycle Power Plant#1 Start Process

As described above, after opening the entire system, for Supplying power to GyeongIn Northern area, the primary transmission line shown in Figure 1 is energized and finally PoCheon Combined Cycle Power Plant is restored.

The PoCheon Combined Cycle Power Plant receives the power from the self-starting generator through the primary transmission line, and then prepares to start the motor load for the GT#1 start. At this time, GT#1 is first activated and GT#2 and ST#1 are activated using the power output from the GT#1. Figure 2 shows the start-up procedure of GT#1 in terms of motor load.

Restoration Procedure Simulation

PoCheon Combined Cycle Power Plant#1 Start Process Simulation

Looking at the GyeongIn Northern area primary transmission line in Figure 1, it consists of a long distance line (About 153.124km) from the self-starting generator, ChunCheon Hydro Plant#1 to the Pocheon Combined Cycle Power Plant. When long distance transmission line is energized, various problems such as ferranti may occur. To prevent this problem, it is necessary to shorten the primary transmission. This can be expected to shorten the restoration time. Therefore, in this paper, simulation is performed considering BESS installation location as follows

1) ShinPoCheon S/S

| Load                | Capacity |
|---------------------|----------|
| Internal load       | 2[MVA] (pf 0.95) |
| Start Motor         | 2000[hp] |
| Oil Pump            | 75[kW]   |
| Water injection pump| 150[kW]  |

The load configuration for simulating the restoration procedure of PoCheon Combined Cycle Power Plant#1 is shown in Table 1 below. Three motors with relatively large capacity (starting motor, oil pump, water injection pump) were set as the motor load and set to 2[MVA](pf 0.95) inside the
plant load. The simulation scenario is based on the generator start procedure in Figure 3. Table 2 shows the restoration procedure simulation scenario. The simulation system was constructed using PSCAD / EMTDC.

Table 2. Simulation scenarios.

| [s] | Contents |
|-----|----------|
| 0   | #1 BESS Start, #2 BESS Start |
| 5   | PoCheon Combined internal load pressure (2[MVA], pf=0.95) |
| 7   | Start Motor, Oil pump Start |
| 25  | Starting motor separation |
| 26  | Water injection pump start |
| 50  | Simulation Termination |

Figure 3. Simplied Simulation System one-line diagram.

**PoCheon Combined Cycle Power Plant#1 Start Process Simulation Analysis**

Figure 4. Voltage profile_Installed ShinPoCheon S/S (Vrms[△]:PCS Voltage, Vrms_grid[□]: grid Voltage).

Figure 5. Motor starting speed.

Figure 6. Voltage profile_Installed ShinPoCheon S/S_battery voltage was incresed (Vrms[△]:PCS Voltage, Vrms_grid[□]: grid Voltage).

Figure 7. Motor starting speed_battery voltage was incresed.
When the Pocheon Combined Cycle Power Plant#1 shown in Figure 3 is simulated through PSCAD/EMTDC, battery voltage and the system voltage are measured as shown in Figure 4. In 5 seconds, the oil pump and the starting motor started to running due to the voltage from the battery. However, the system frequency was stabilized at 60Hz, but after 25 seconds, the starting motor did not reach the rated value of 1.0 [p.u] and dropped.

So, to match the rated speed of the starting motor, the initial battery voltage was rised to 2.4[kV] to compensate for voltage drop.

As a result, the initial battery voltage was increased to 1.3 [p.u] from 1.1 [p.u] and the grid voltage increased from 0.9 [p.u] to 1.0 [p.u] and it was confirmed that the starting motor also reached the rated speed.

**Conclusion**

In this paper, the restoration process using BESS for Korean primary transmission system was simulated and analyzed using PSCAD / EMTDC. Since BESS is free from limitation of position and distance of self-starting generator, in this paper, BESS is installed close to primary power plant. Simulation results show that a voltage drop was occurred due to the influence of line length when the transmission line is energized. At this time, as the large capacity electric motor is started, additionally, voltage drop was occurred for the starting current. Excessive voltage drop caused start failure for the starter motor. In order to solve this problem, the initial voltage was increased and energized, and as a result, the start motor was successfully started. Therefore, when replacing the self-starting generator using BESS, Sufficient simulation analysis is needed because it can be affected by various system conditions.

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