A1-PS1

Rorating Electrical Machine

244_2022

Performance Evaluation of Retrofitted Coal-fired Plant Simulation Model

Bongil KOO*, Suchul NAM, Baekkyoung KO, Sungbum KANG,
Joon HAN, Karam HAN, Byeongseon CHOI
Korea Electric Power Corporation Research Institute

Motivation

- The type of generator within the power grid is rapidly changing from rotation-based generators, which are output-adjustable and provide inertia, to inverter-based renewable energy. [1-2]This change to an environment-friendly configuration has become a challenge to power system operators who supply electricity with a constant voltage and frequency despite disturbances such as supply-demand imbalances and failures. In particular, we need fast and large backup resources to balance demand and supply in response to the rapid fluctuations in renewable energy output at sunrise and sunset.[3] However, the costs of constructing power facilities amid civil complaints, etc., have become major obstacles to the establishment of new facilities, and when considering the value of existing facilities and the economic ecosystem surrounding them, it may be of great advantage to utilize these existing facilities.

Objects of investigation

- The installed capacity of coal-fired T/Ps is gradually shrinking due to carbon neutrality, the change to renewable energy, etc. The sunk costs of facilities and costs for site conversion have also considerably increased. Suppose we can utilize such old coal-fired T/Ps to make flexible coal-fired T/Ps that are capable of changing output as gas turbines are. In that case, we can respond to the power supply-demand unbalance caused by the change in the output of renewable energy sources while providing a comparatively large capacity of inertia at the same time. This can be a cost-effective means of enhancing the stability of the system. In this study, we tried to determine what improvements are needed for conversion to such a flexible coal-fired T/P, modeled the flexible coal-fired T/P created through such improvements, and finally simulated the effect of the flexible coal-fired T/P on the line overload when applied to the system.

Method/Approach

- The principal technical indicators of flexible operation are minimum stable load response speed (ramp rate) and start-up time. When lowering the minimum stable load of the power plant and thus expanding the output range, the room for renewable energy can get larger. However, in this case, in low-load operation, the number of risk factors increases because the performance of each piece of equipment is degraded, and the plant is operated in an unstable state. In addition, when improving the speed of the load response, the responsiveness to the load change of the power system is also improved. However, taking into account the operating environment of the power plant, improving the load response speed is restricted to some extent. The principal limiting elements in the aspect of equipment are boiler combustion stability during low-load/varying-load operation, an increase in the thermal fatigue/corrosion tendency of the heat transfer piping and structure support, low-temperature corrosion of exhaust gas ducts, a decrease in de-nitration catalyst activity, low exhaust gas temperature in the stack, insufficient capacity and load-following capability of the desulfurization facility, etc., and technology is being developed to address these issues.

- To evaluate the effect of applying a T/P whose flexibilities have been enhanced on the system, we developed an analytical model for the flexible coal-fired T/P first. In the case of the PSS/E from SIEMENS, which is one of the most widely used tools in system analysis, only models for generic power facilities are provided, and for specific facilities or other facilities which users may want to utilize, the users have to create a corresponding user-defined model (UDM). Also, in PSS/E, there is no model for prime movers, and only models composed of turbines and governors are provided. So the model cannot reflect all the enhancement processes for the flexible coal-fired T/P mentioned above. However, modifications to create similar response characteristics are possible.

A1-PS1

Rorating Electrical Machine

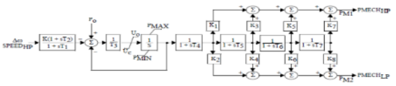
244_2022

Performance Evaluation of Retrofitted Coal-fired Plant Simulation Model

Bongil KOO*, Suchul NAM, Baekkyoung KO, Sungbum KANG,
Joon HAN, Karam HAN, Byeongseon CHOI
Korea Electric Power Corporation Research Institute

Experimental setup & test results

- Three items need to be enhanced for an ordinary coal-fired T/P to become a flexible coal-fired T/P. The first item is a reduction in start-up time. This is unnecessary for the system stability simulation with which we do the static analysis or short-time (several seconds) analysis, which are the main targets of this paper. The second one is the minimum stable load, and no specific model is necessary for the simulation of this item because it can be simulated by reducing the generator output down to 40% of the rating. The last one is enhancing the output increasing/ decreasing performance. However, there is no parameter for directly adjusting the ramp rate of the generator in PSS/E. Therefore, in PSS/E, the goal of such analysis model is to enhance the ramp rate (%/min), which represents the capability of increasing/decreasing the output in terms of percent of the rated output, from 3%/min to 5%/min, which is similar to the ramp rate of ordinary gas turbine generators.
- Prime movers have not been modeled in PSS/E. This is because detailed modeling is not necessary for mechanical equipment. In PSS/E, the IEEEG1 model shown below is used.



- IEEEG1 is a steam governor model composed for frequency response or primary control, and it adjusts the amount of steam based on the measured turbine speed. In this model, if the system frequency goes down, the steam flow is increased, and the turbine speeds up, and if the system frequency goes up, the steam flow is decreased, and the turbine slows down. This is because the system frequency is synchronized with the rotation speed of the generator. The system frequency is controlled to be the rated frequency through such manipulation. Here, the manipulation being related to generator output adjustment, K represents the droop characteristics of the governor, T1 and T2 are the time constants of the lead-lag compensator, and T3 and U0 are the parameters related to the opening/closing of the steam supplying valve, representing the time constant associated with the speed of the servo motor and valve opening speed, respectively. K1~K8, T4~T7 are parameters of the stage cross-compound steam turbine. T4 ~ T7 are time constants representing the dynamics of the reheater stages, and K1 ~ K8 are gains related to the reheater stages. Normally K1, K3 are used and sum of them is become 1. The others set to be zero. Adjusting the factor K1~K8 means retrofit of turbine's structure and also needs a lot of cost and validation of design, we don't consider in this paper.

- In this study, among the parameters mentioned above, we adjusted the time constant and gain of the governor, which have a great influence on the generator output while not affecting its unique properties, and checked the change in output. In the simulation, we measured the time taken for the change in generator output when adjusting the output instruction by 0.1 PU in PSS/E and additionally checked overshoot or settling time. First, we changed the parameters of an 800 MW class generator, and the results were as shown in the figure below.

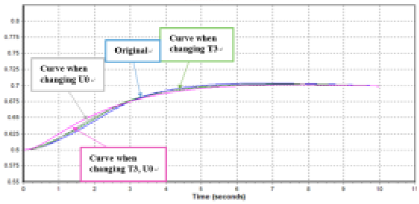


Figure 2. Changes in output due to the change in U0,T3

- We adjusted T3 and U0 separately and then adjusted both of them. We can see that, in three cases, the curves maintain similar characteristics as the original one. The simulation results for the 500 MW, 800 MW, and 1100 MW generators have been compared in the fig.3 below. This shows that the smaller the capacity, the faster the generator's response.

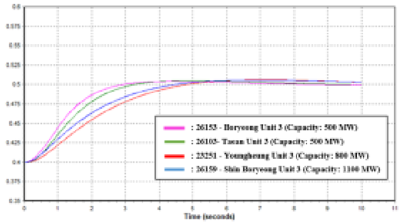


Figure 3. Response times of generators with different capacities

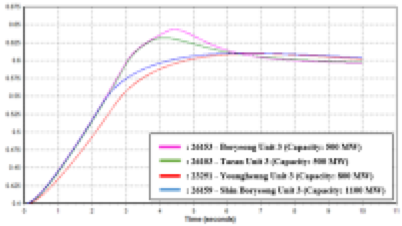


Figure 4. Overshoots of generators with different capacities

A1-PS1

Rorating Electrical Machine

244_2022

Performance Evaluation of Retrofitted Coal-fired Plant Simulation Model

Bongil KOO*, Suchul NAM, Baekkyoung KO, Sungbum KANG,
Joon HAN, Karam HAN, Byeongseon CHOI
Korea Electric Power Corporation Research Institute

Experimental setup & test results(con.)

- The fig.4 above shows the response patterns of generators when they received instructions to increase the output by 0.2 PU. As a result of the simulation, we could see that the smaller the capacity of the generator, the greater the overshoot that occurred. Therefore, we could see that, to make a generator a flexible resource, changing the parameters K and K1 is more effective than changing U0 and T3, and smaller generators respond faster but have a greater overshoot, so we cannot create the required response pattern by making one gain too big.
- With such characteristics, by making the outputs of the T/Ps similar to those of gas turbines, we finally implemented the flexible coal-fired T/P, as shown in the fig.5 below. By changing K and K1 properly, we made the output of a T/P almost the same as that of a GT, and the actual time taken for changing the output, in terms of the time taken for a 0.1 PU increase when compared with an ordinary T/P, was reduced to 66%.

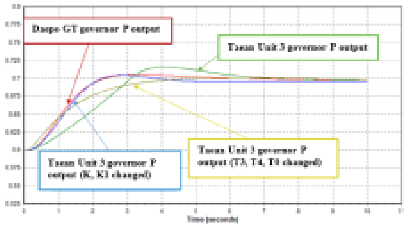


Figure 5. Output curves of coal-fired T/Ps (Existing T/P, T/P with changed K and K1, T/P with changed T3, T4 and U0) compared with a GT

- In the case that flexible coal-fired T/Ps are applied, in the aspect of the power system, responses to the imbalance between demand and supply can be performed well due to the increase in the number of generators capable of adjusting the output. In this study, we applied flexible coal-fired T/Ps to the 2031 real power system in Korea based on the flexible coal-fired T/P analysis model described in the previous chapter and evaluated the effect of those flexible coal-fired T/Ps on the system. If flexible coal-fired T/Ps are applied, we can reduce the output of remote generators under operation to cover the base-load, and the line load factor or loss can be reduced accordingly.

- The minimum stable load of flexible coal-fired T/Ps is about 40% of the rating. Taking this as a condition, we reduced the output of the remote, flexible coal-fired T/Ps by 1 GW and increased the generator's output near the demand by 1 GW to check the change in the line load factor. As a result of the analysis, when considering the enhancement of the line load factor, it was more effective to deploy the flexible coal-fired T/Ps on the east coast rather than the south or west coast. We need to establish a deployment plan through additional study

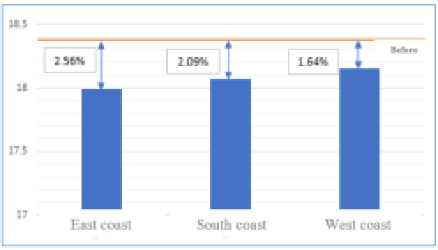


Figure 6. Enhancement of the line load factor compared with the current value

Conclusion

- The purpose of this study is to retrofit old coal-fired T/Ps into flexible T/Ps and to evaluate the effect the flexible coal-fired T/Ps have on the power system when applied. We expanded the range of output adjustments through enhancements to plant boilers, heat transfer piping, desulfurization facilities, control systems, etc., and increased the speed of output increase/decrease, and thus, improved the flexible coal-fired T/P; we also established an analysis model for evaluating the effect that flexible coal-fired T/Ps would have on the system when applied and performed a simulation. As a result, we found that flexible coal-fired T/Ps effectively mitigate overloaded lines when successfully retrofitted and incorporated back into the power system. However, this study has focused on implementing flexible coal-fired T/Ps. Thus, to use high-reliability T/Ps in the system, further studies into the change in generator efficiency, increase of fatigue, etc., that can occur during facility retrofit are required, along with a continuous accumulation of operation data