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Research paper

A Study about the Power System Effect by Load Following of Nuclear Power Governor Control

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Abstract

Background/Objectives: Nuclear power generator has no emission of CO_2 and has been presented as a practical alternative to prepare for climate change conversions and to promote energy independence.
Methods/Statistical analysis: The load pattern was analyzed using the power system prediction data of 2024 year. Nuclear power system analysis has been changed the governor operating rate within the rage of acceptable performance by the speed droop of standards, in consideration of the safety of the power plant. The frequency variation limit has been evaluated the power system by applying the N-2 generator contingency.
Findings: The system frequency should be constantly output when the load fluctuates. However, large load fluctuation was occurred according to the power system frequency was deviate from the operating standard. The frequency recovery of the power system reference for stable system operation reduces the frequency fluctuation by securing reserve power of the generation. Nuclear power generation was used to secure large capacity reserves. The control of nuclear power has been studied by used governor control.
Improvements/Applications: It was possible to obtain coast-effective results than the hydro-generator operation of the momentary reactive reserve for conventional governor droop control. Nuclear power could be controlled by various operating methods, and could be used as friendly environment energy through reduction of CO_2 in the environment side.

Keywords: Load Following, Nuclear Power, Governor Control, Droop Rate, Load Fluctuation, Frequency, Power System

1. Introduction

A power system should be matched between supply and demand power that was adjusted according to the demand for ever-changing generation power. Recently, power supply bas been difficult due to change the domestic climate. A large-scale power generation facilities were under review that has been increased the electric power demand. Nuclear power generation as large-scale power supply has no CO_2 emission, and it was presenting as a practical alternative to prepare for climate change convention and to promote energy independence[1]. Nuclear power generation has been operating continuous operation, which is impossible output control the current operation mode. The nuclear power baseload modes have constant load or scheduled load operation. The scheduled load mode has tended to be replaced by the more flexible mode of frequency control or arbitrary change of load in the upper power range of about 15~30% of rated power. Variation is normally less than 1-2[%/min] but a change of load of up to 5[%/min] or even 10[%/min] is sometimes required over a limited range. The load-following method has been controlled the output in response to the demand fluctuation in the power system. This method could be reduced the power system operating costs and maximize energy efficiency. In particular, nuclear power of Europe has been operated by controlled the load-following. The nuclear power of France has been operating to exceed 75% of the whole power generation capacity. Germany has been used to load-following method the 3 nuclear power generation along by using France's power generation[2-4]. In most other countries, it was used the load-following as the other type power than nuclear power.

This paper was studied about the power system effect by using the load-following of the nuclear power. The frequency variation of the power system has been evaluated by N order contingency. The power system load should be managed for stable system in the off-peak and peak load system. In fault state of the power system, the frequency should be operated on the basis of the power system operation. The change power generator by using the domestic power supply and demand plan of 2024 year. It has been simulated to study on change the power system frequency by dropping the nuclear power generator by using the power supply and demand plan. This paper was investigated the frequency control characteristics of nuclear power generators and instigated the improvement of the power system stability with the recovery of the power system frequency through the governor control of the generator.

2. Simulation of the Power System

2.1. Governor Model and Operating range

2.1.1. Governor Model

The regulator model of the nuclear power generator has been modified by PSS/E program[5-7]. The governor is controlled the frequency by adjusting the supply valve fo the steam in the generator. The governor controller model was the nuclear power generator as shown figure 1 and 2. Domestic nuclear power generator model has been using the IEEEGO and IEEEG1 model. Most nuclear power has been applied as the IEEEG1 model excet from the Kori generagtor.

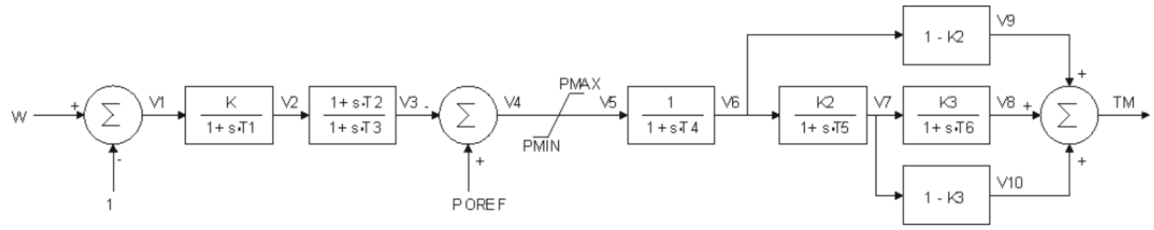

Figure 1: IEEE Standard Governor Model

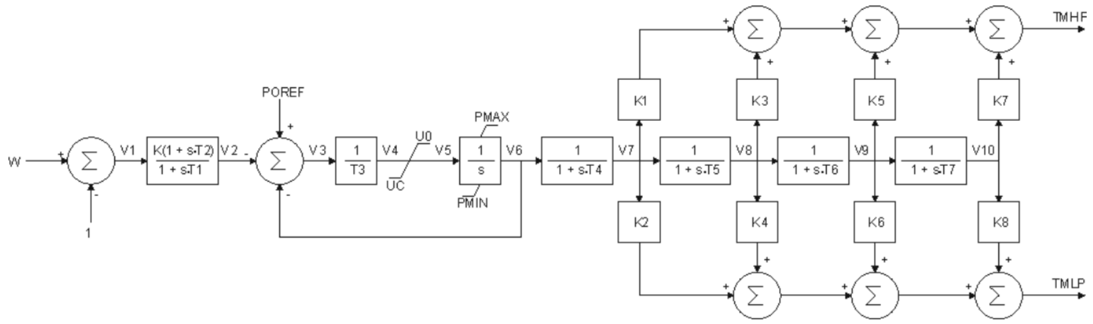

Figure 2: IEEE Type 1 Speed-Governor Model

2.1.2 Operating Range

It was the participation, response speed and allowable range of the load-following of the power system of nuclear power plant as shown table 1. Mode A and G was shown the control limits of nuclear power plants in Europe[8-10]. The Mode K(domestic nuclear control mode) could be controlled up to ±2.5% at the speed of 0.5[%/sec] as Frequency control with the fastest control characteristic in nuclear power generation. The momentary reserve could be controlling up to 10% at a rate of 2[%/min]. Therefore, it is possible to output a net reserve within a maximum of 5 minutes. The power output can be reduced to 50% from 100% at up to 2 hours with load tracking with the slowest control characteristic.

Table 1: Operating limit by control speed of nuclear power

Need of the power system		Mode A	Mode G	Mode K
Load-following	Power range (% of rated power)	30~100%	30~100%	50~100% @ 2[h]
	Variation (%rated power/min)	0.3[%/min]	2[%/min] @ 1day	3~5%
Momentary Reserve	Size and Rate of power incensement	+15~20% 5[%/min]	5[%/min]	2[%/min]
Frequency control	Auto(local)frequency control	±3%	±3%	10%
	Load control	±3%	±5%	±2.5%
	Variation range	1[%/min]	1[%/min]	0.5[%/sec]

2.2. Case Study

The reserve power for stability of the power system is GFC (Governor Free Control), AGC (Automatic Generator Control), and reserve capacity of the generator. In case of the power system failure, FRC (Frequency Response Characteristic) with frequency response is a characteristic for keeping the frequency of the system stable in response to load fluctuation. It is reserve power that could be automatically reacted instantly according to GFC and AGC operation. The power system could be operating normally as the frequency would be change by the load fluctuation. The frequency maintenance goal has been divided into two types. First, the frequency operation target for the normal operation of the power system is 60±0.2[Hz], and it is stipulated by the Electricity Business law. Second, steady frequency protection guidelines for power plants specified by ANSI/IEEE for frequency maintenance range from the point of view of life of turbine generator as 60±0.5[Hz] is continuous operation range without affecting turbine generator life. The system frequency has been varies depending on the load change in the power system. it has been the degree of imbalance between power generation and demand. The frequency response was depending on the governor response characteristics of the generator, load characteristics, etc. Therefore, The response characteristics of the power system are expressed as follows equation 1.

$$\text{FRC}\ [\%/Hz = \text{k}\left(\frac{\text{dP}}{P_o}\right)\frac{1}{dF} \qquad (1)$$

Here, k is power system parameter, dP is shortage power, dF is frequency error by shortage power, P_0 is power system load.

2.2.1. Simulation Scenario

The power system data was used to base on the 5th power supply plan of Korea Power System in 2024 year[11]. The peak load and off-peak load were selected according to the operation power. The generation power amount was maximum value(93,617.2[MW]) and minimum value(57,806.1[MW]) by power system load as shown Table 2.

Table 2: The generator capacity in power system

Load	Number of Generator [MW]		Gen. Cap. [MW]	Max. Gen. [MW]	Min. Gen. [MW]
	Total Gen.	Operating Gen.			
100% (peak)	353	241	93,617.2	98,159.4	59,947.2

60% (off-peak)	353	84	57,806.1	59,569.0	41,647.2

The off-peak load of the power system has owned the low capacity value by the economy dispatch. This situation was decreased the load-following ability in case of failure the large-capacity generator (1,000[MVA] in each capacity). The system frequency variation by the simulation confirm in case of the two nuclear power plants fault at the off-peak and peak load. The system power scenarios for the simulation was set as follows.

1. Check frequency in basic power system.
2. Check frequency by controlling droop value of generators in basic power system.
3. Check the system frequency by controlling governor gain of nuclear power.

The power system frequency was adjusted by controlling the governor gain for improving the power stability. The power system stability was simulated by the variation of the system frequency and the frequency recovery rate by elimination the large capacity generator as shown Table 3. At this time, it has been controlled the governor gain(K = 1/R) of nuclear power generator.

Table 3: Set the governor droop rate (K=1/droop) on the nuclear **power generator**

Case Study	K value	Comment
Base Case	Base data	Power system planning data of 2024 year
Case 1	0	Locked the governor control of Nuclear power
Case 2	5	Setting the 0.2(1/K) as the governor droop of nuclear power
Case 3	15	Setting the 0.067(1/K) as the governor droop of nuclear power
Case 4	20	Setting the 0.05(1/K) as the governor droop of nuclear power

2.2.2. Simulation Result

The power system simulation has confirmed the system frequency fluctuation by dropping the nuclear power in the large capacity generator. The simulation result was shown the fluctuation frequency by failure in nuclear power generators as shown Figure 3 and Figure 4. The system frequency has been shown fluctuation capacity in the peak load and off-peak load of the power system in case failure of two nuclear power (Uljin #1, #2) as shown Figure 1 and Figure 2. In case of the peak load, the drop-out of the generator has been showed that the frequency variation and the frequency recovery rate were fast due to the large amount of operation and reserve power of many generators.

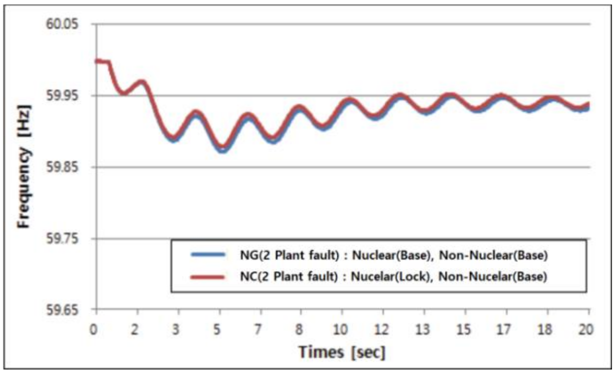

Figure 3: Change capacity of power system frequency by failure in two nuclear power generators in case of peak load

In case of the off-peak load, some generators have been used due to the stoppage and the maintenance of the generators. So, the system frequency was large fluctuated due to the drop of the large capacity generator.

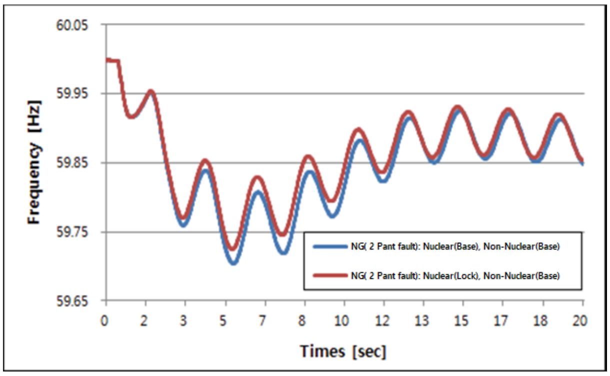

Figure 4: Change capacity of power system frequency by failure in two nuclear power generators in case of Off-peak load

2.3. Review of the Power System state

The frequency fluctuation has been checked for case study by fault in nuclear power which was large scale capacity generation. It was K(droop) value of the governor of nuclear power due to the domestic power supply and demand plan as shown table 4.

Table 4: Governor Gain of the Nuclear Power (in case of base Power System)

K value	Nuclear Power (Count of Plant)	Number of total Pant
0	Kori(3), Wolseong(1), Youngkwang(5), Uljin(4)	13 Plant (38.2%)
5	SinKori(6), SinUljin(4)	10 Plant (29.4%)
12.5	Wolseong(3)	3 Plant (8.8%)
14.3	Kori(1)	1 Plant (2.9%)
20	SinKori(2), SinWolseong(2), Youngkwang(1), Uljin(2)	7 Plant (20.6%)

The governor gains(K) of nuclear power generation was adjusted from 0 to 20 as shown Figure 5. In case of the off-peak load (60% of load level), the governor gain of the nuclear power generator would be adjusted as shown in Table 4.

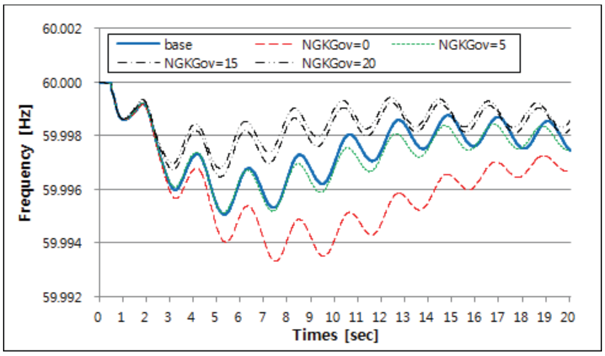

Figure 5: The system frequency by adjusting the nuclear power governor gain in case of the off-peak load

When the governor gain was zero (that is, governor lock), the system frequency was shown the largest fluctuation because it was not adjusted by the reserve power of the nuclear power plant. The fluctuation of the system frequency was shown changed small when the governor adjustment was large. It was appeared that the stability of the system was ensured by load-following in accordance with the frequency change.

4. Conclusion

The reserve power of the generator has been calculated by excluding the amount of power currently being output by the generator at the reactive power limit of the total generator in the power system. However, the reactive power has local characteristics unlike frequency, not all generators have the same effect on the voltage control of the system. It was necessary to calculate the new utility reactive power reserve which quantifies the reactive power value by applying the weight to the generators having a large influence on the voltage maintenance of the main points of the system. Nuclear power generators have frequency tracking ability, but due to safety problems, it wouldn't be controlled frequency by using speed droop.

In this paper, the simulation was proposed the stability of the system rather than the safety of the nuclear power plant. It has been reviewed about affection of the increase of power demand on the system due to the increase of the ratio of nuclear power in the power system. It has been confirmed that the recovery of the system frequency the generator by controlling the droop gain according to drop-out of the nuclear power.

Simulation results, it was shown that the system frequency was restored by regulating the governor gain of the nuclear power generator. It would be improved the stability of the power system by monitoring the load of the nuclear power generation in the power system. In the future, it will be necessary to study the safety of the nuclear power generation due to the load-follow and to control the governor gain of each nuclear power generator.

It was considered that the study on the operation of nuclear power generation and the level of optimal supply reliability in the power system. It should be continued as a basic study on the type of reserve required in the system and the dependency of load on the reliability of nuclear power generation.

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