ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

A Influence of increasing the Renewable Energy in the Power System

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Abstract.
BACKGROUND/OBJECTIVES: Power system has been expansion of renewable energies such as solar and wind power. It is expected to cause a lot of uncertainty in the operation of the power system and the power market. The fluctuation of electric power demand increases with the increase of renewable energy. So, research is need to conduct on securing more reserves and rapid power generation resources in the power system.
METHODS/STATISTICAL ANALYSIS: Renewable energy is effect on the power system stability by fluctuations in the output of wind and solar power. It has been analyzed operational reserves, frequency adjustment capability of the conventional generator. As a result, the coefficient of inertia of the generator operating the existing power system has been lowered from about 4.406 to 3.276 due to increasing the renewable energy power source.
FINDINGS: The expansion of new and renewable energy is decreased the coefficient of inertia in the power system. It will be expect to decrease the stability of the system due to the disturbance of the system and occur the power outage.
IMPROVEMENTS/APPLICATIONS: Operating the renewable energy is weakens stability in the power system. It is participate as load during the daytime and, power generation during the morning and evening hours by using the PSP or BESS in order to improve the reliability of the power system.

Keywords: Renewable Energy, PSP (Pumped-Storage Plant), BESS (Battery Energy Storage System), Power System.

1. INTRODUCTION

Recently, renewable energy has been increased the interested to global warming caused by carbon emissions. The proportion of solar and wind power is increasing as a way to reduce the power output of existing diesel, gas, and nuclear power plants in the power system [1-3]. The power supply in 2034 is planned to have a facility capacity of 190.2GW and an effective capacity of 125GW according to the 9th power supply and demand plan in Korea [4]. The ratio of each facility is 10.1% for nuclear power, 15.0% for coal, 30.6% for LNG, 40.3% for renewable energy, and 3.4% for pumped water. Renewable power capacity is the largest at 77.8GW (solar power 45.6GW, wind power 24.9GW). The effective capacity ratio of new and renewable energy was 8.6%, which was reduced to about 1/8 of the rated capacity ratio, so it was considered that only 10.8GW of the rated capacity of 77.8GW would contribute at peak load.

Table 1: Unit of power supply in 2034 (effective capacity takes into account peak contributions)

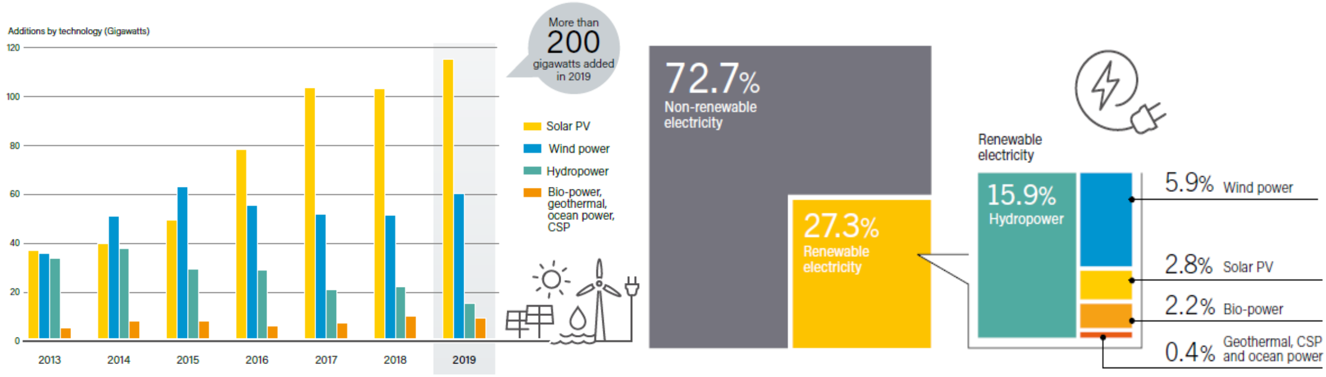
	Nuclear	Coal	LNG	Renewable	PSP	ETC.	Sum
Rated cap.[GW]	19.4	29.0	59.1	77.8	6.5	1.2	190.2
Ratio	10.1%	15.0%	30.6%	40.3%	3.4%	0.6%	100%
Active Power[GW]	19.4	28.3	59.1	10.8	6.5	0.9	125.0
Ratio	15.5%	22.7%	47.3%	8.6%	5.2%	0.7%	100%

It is difficult to supply power normally, since the power generation of the renewable energy was varies depending on the natural environment. This study is proposed to investigate the output of the existing generator as the proportion of photovoltaic power generation increases in the existing power generation power. It was considered for method to stabilize the fluctuation of the power system according to the photovoltaic power output.

2. OPERATING THE POWER SYSTEM

2.1. RENEWABLE ENERGY

The renewable energy has rapidly progressing as shown in figure 1 [3]. It has been maintaining the more than 8% average growth rate of installed renewable power capacity over the previous five years. The incensement of renewable power generation capacity has been outpaced installations of both fossil fuel and nuclear power capacity combined for the fifth year in a row. Installed renewable energy capacity was provided an estimated 27.3% of global electricity generation at the end of 2019.



(a) annual addition of capacity (b) rate of share

Figure 1. Estimated renewable share of global electricity production, End-2019.

2.2. ANALYSIS METHOD OF THE POWER SYSTEM

Frequency would be changed occur due to constant load fluctuations under normal conditions in the power system. The load frequency control has been maintained this frequency within a certain range. It is necessary to have the ability to clearly grasp the fluctuation characteristics of the disturbance acting and to restore the frequency within an appropriate time in order to maintain the prescribed frequency.

2.2.1. DYNAMIC MODELING AND CONTROL CHARACTERISTICS TIME CONSTANT

It would be expressed by the differential equation of the equation that is dynamic properties of a rotating machine connected to a dynamometer and operating independently as shown the formula (1).

$$\frac{Md^2\theta}{\omega_0 dt^2} + D'\frac{d\theta}{dt} = P_i - P_o \qquad (1)$$

Here, M ($=I\omega^2$): I is the moment of inertia, θ is phase angle, ω_o is reference angular velocity [rad/sec], D' is Braking coefficient of the rotating machine, P_i is rotator input and, P_o is rotator output.

The frequency of the system is changed the number of rotations of the rotor load changes and the power consumption changes. The generator input has been adjusted the output to recover the system frequency by the governor operation due to the system frequency change. Therefore, the frequency equation has been formula is the system considering the normal generator input (P_{Gin}) and the change in power generation ($\mu(\Delta f)$) caused by the governor operation as shown the formula (2).

$$M\frac{df}{dt} + Df = P_{Gino} - P_{Lout} - \mu(\Delta f) \qquad (2)$$

Here, f is frequency [Hz], PG is generator input, PL is load, and μ is change in power generator by frequency.

The time constants related to the governor and turbine was effected to the adjustment spectrum among the characteristics of devices related to frequency control. It has been used in the actual simulation, the electric type has been about 0.3 seconds and the mechanical type is about 0.5 seconds in the case of a large-capacity generator (600MW). The dead-band was about 0.02~0.1% (0.02~0.06Hz at the reference frequency of 60Hz) in case of a hydraulic power generator, and a similar value was applied to a thermal power generator.

2.2.2. FREQUENCY CHARACTERISTICS IN THE POWER SYSTEM

The system frequency characteristic is the sum of the load frequency characteristic constant in the system and the generator frequency characteristic constant as shown the formula (3).

$$K = K_G + K_L \qquad (3)$$

Here, K is frequency characteristic constant (system constant), K_G is generator frequency characteristic constant, and K_L is load frequency characteristic constant.

If it was occurred the supply and demand error as much as ΔP (=P_G - P_L), the frequency fluctuation (Δf) has been $K/\Delta P$.

2.3. CASE STUDY

2.3.1. WEEKLY DAILY IN THE POWER SYSTEM

It was shown the daily load curves for January (winter) and July (summer) 2020 as shown in figure 2 [5-7]. Demand has been showed relatively less demand in the morning and evening than during the daytime. It has been seemed that the output of the load curve was lowered because industrial electricity wasn't used on morning and evening time.

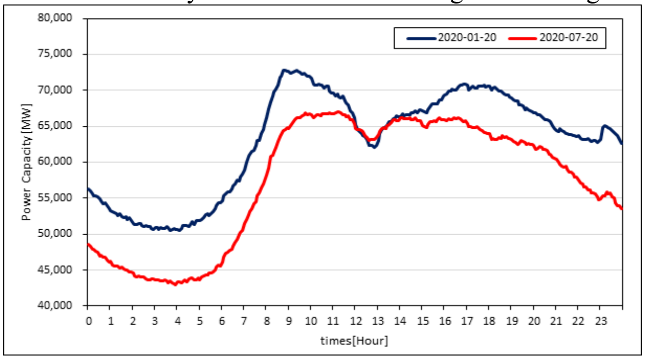


Figure 2. Daily load curve by season in the power system (2020year)

It would be appeared the power generation facilities and load capacity by predicting the load in 34 according to the daily load curve in 2020 as shown in figure 3. Renewable power output is changed according to changes in natural conditions (weather conditions such as sunlight, wind speed, temperature, etc.). It is impossible to control the output as a power source by depending on the power demand. In addition, the power generation output would be significantly decreases during the peak time of power demand, from 3pm to 5pm in summer or evenings in winter. The PV power has been maximum output in the peak sunlight period (12~13 o'clock). The output was increases close to the facility capacity, so other power sources should be stopped or output decelerated to meet the power supply and demand conditions. Therefore, renewable power should be establish a power supply and demand measure to sufficiently respond to the characteristics.

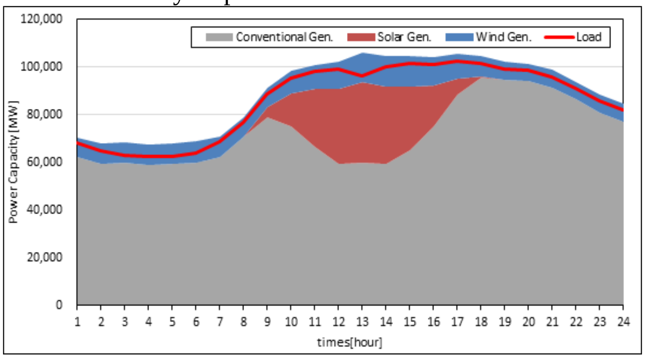


Figure 3. Predict of daily load curve by generation source in the power system

2.3.2. SIMULATION MODEL

The power system was studied using IEEE 39 Bus as shown in figure 4 [8-10]. It has been performed load fluctuation reference to the system. Solar power generation has been currently operated at about 7.3% of the system in Korea, but plans to increase it to 21% in 2034 years. Based on this, the simulation has been compared with the existing solar power and the power generation power according to the change in solar power capacity in the future.

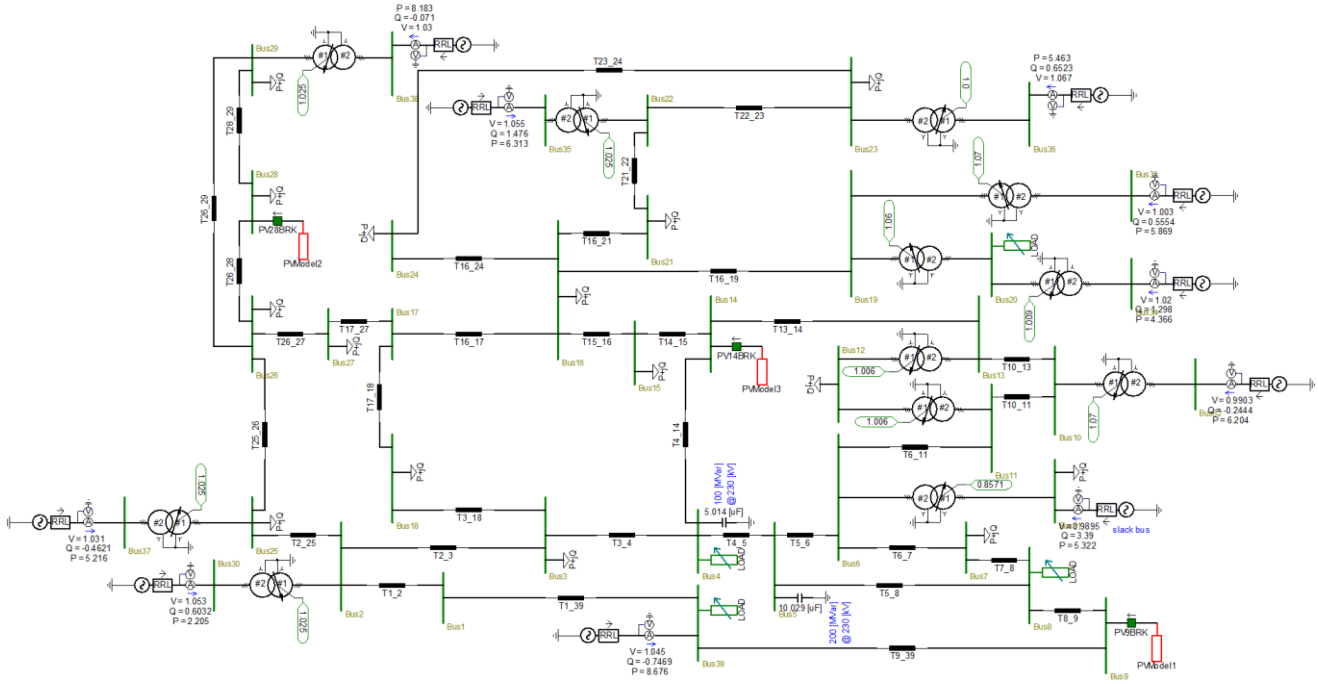


Figure 4. Added PV system in the IEEE39 Bus power system

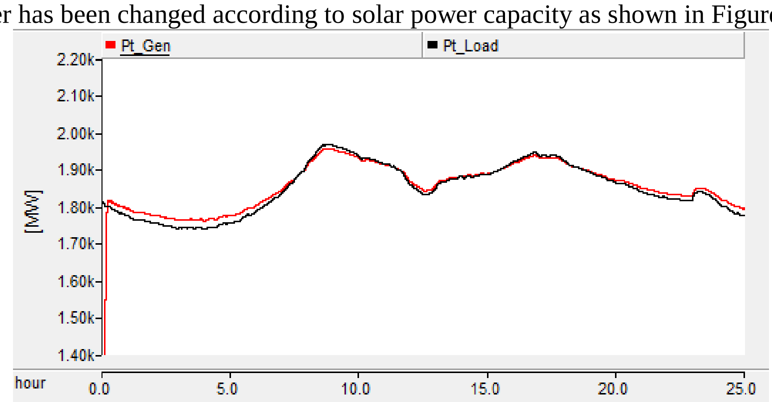
It has been shown simulation scenarios in the power system as shown in Table 2. Case 1 was reviewed the load-following of conventional generators according to load fluctuations. Case 2 has been the current PV generation ratio added in Case 1. The power system generation and load-following of the conventional generator was reviewed. Case 3 has been the estimated PV generation ratio of 2034 year added in Case 1. The power system generation and load-following of the conventional generator were reviewed.

Table 2: Simulation scenario for case study

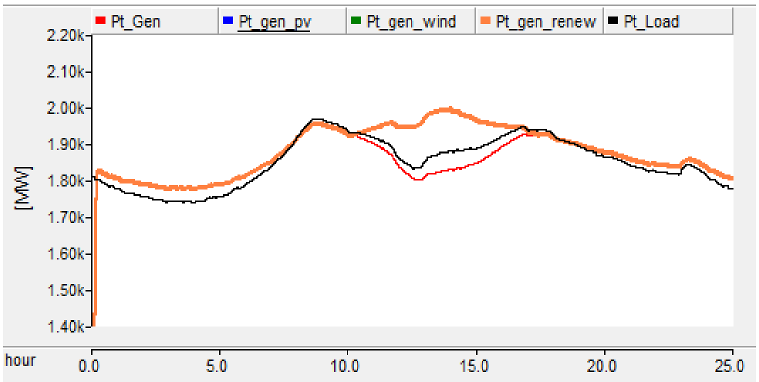
Case	Scenario	Contents
Case 1	Base	Operating the conventional generator by daily load fluctuation
Case 2	Base & PV(1)	Added the present PV generation ratio in the case 1
Case 3	Base & PV(2)	Added the estimated PV generation ratio in the case 1

2.3.3. CASE STUDY

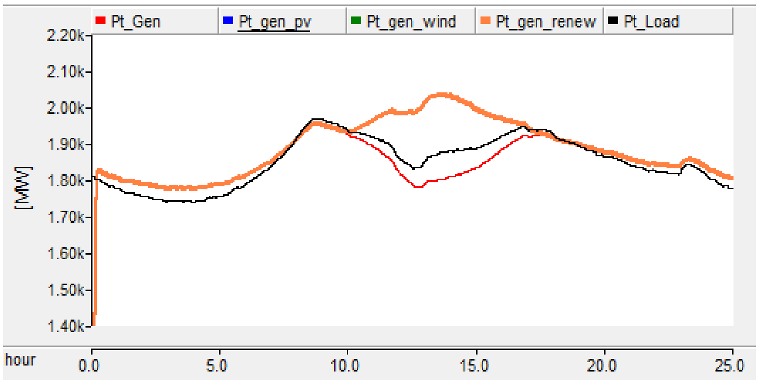
The power generation power has been changed according to solar power capacity as shown in Figure 5.



(a) Case 1: Base Case



(b) Case 2: Connected the PV system (2024 year)



(c) Case 3: Connected the PV system (2034 year)

Figure 5. Load-following of the power generation by load fluctuation

The curve has been shown the conventional power generation and the load power in the power system as shown figure 5(a). The curve has been shown power system generation and the conventional power generation according to the current photovoltaic power generation as shown figure 5(b). The curve has been shown grid power generation and the conventional power generation according to 34 years of photovoltaic power generation as shown figure 5(c). The power system output has been increases, but conventional power generation was appeared to reduce as the solar power output increases. It has been appeared to large difference power output that the conventional power output control will be more likely to cause problems.

2.3.4. EFFECT OF THE RENEWABLE ENERGY

It was shown an equivalent model for AGC simulation as shown in figure 6. Power system was consisted that the bus 1 is conventional generators and loads, and the bus 2 is renewable energy. The transmission line was inputted by calculated the equivalent admittance in the power system. Simulation was conducted by adding the ESS and PSH of the same capacity in order to examine the influence the renewable generation.

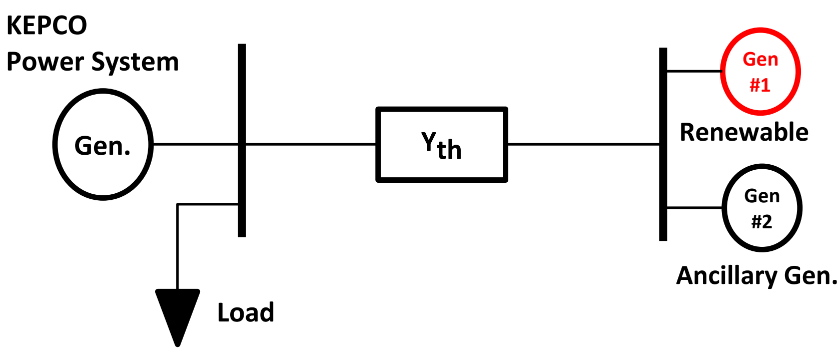


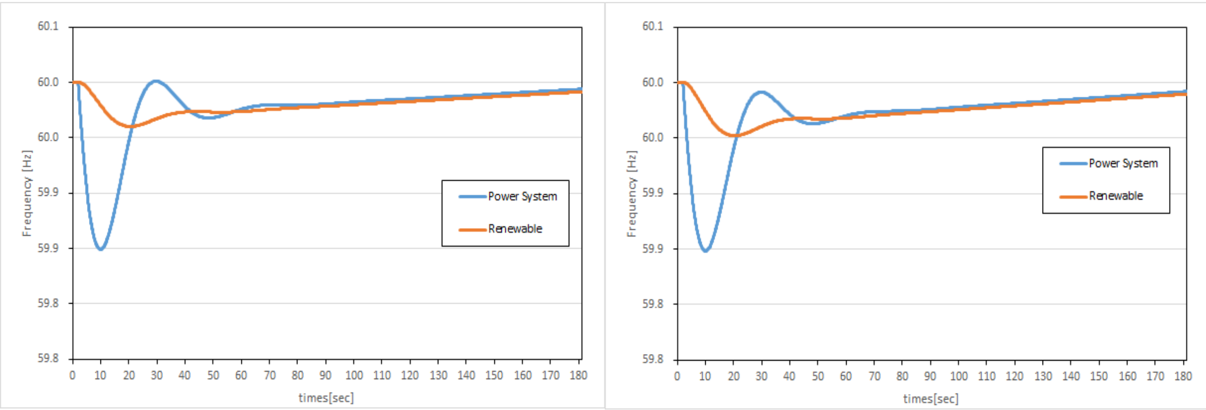
Figure 6. AGC Simulation model in power system5

The coefficient of inertia of the power system according to the fluctuations in power generation capacity and renewable energy based on the PSS/E data for 2024 and 2034 of the Korea Electric Power Exchange as shown in the table 3. This paper was studied to compare the power system in years 24 and 34 to examine the impact of new and renewable energy on the system.

Table 3 : Generation and Inertia in the power system (24 and 34 year)

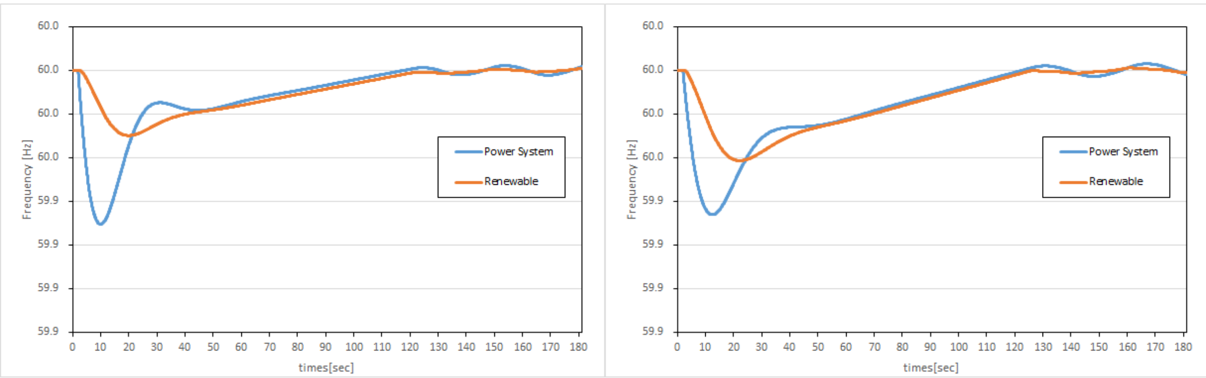
Case	Pg_con [GW]	Pg_rew [GW]	P (ren/con)	H
Case 1 (2024yr)	93.618	6.881	7.35%	4.59
	78.333	2.593	3.31%	4.71
	57.806	0	0.00%	4.84
Case 2 (2034yr)	92.472	20.339	21.99%	3.30
	83.409	4.227	5.07%	3.88
	62.078	0	0.00%	3.93

It was compared '24 and '34 based on data from the KPX (Korea Power Exchange) in the real power system as shown in figure 7 and 8. It was based on the ratio of the inertia coefficient of the generator and the renewable energy of the power system. It has been checked the frequency of the generation power by drop 1,000 [MW] capacity (based on the primary reserve power) in the simulation.



(a) peak load **(b) off-peak load**

Figure 7. Frequency variation by generator of the power system (Case 1)



(a) peak load (b) off-peak load

Figure 8. Frequency variation by generator of the power system (Case 2)

3. RESULTS AND DISCUSSION

The power generation data of 24 and 34 years were compared according to the introduction of new and renewable energy into the power system. It was calculated the inertia force of the power system according to the generation power as using the formula (4). The inertia of the power generation power of the system was calculated according to the daily load characteristics as shown the figure 9.

$$\mathrm{D.F.} = \frac{\sum_i P_i H_i}{\sum_i P_i} \qquad (4)$$

Here i, P and H are the generator number, generator capacity [MW], and generator inertia, respectively.

It could be seen that solar power generation among new and renewable energies has no inertial constant, so the inertia power decreases in the afternoon and daytime.

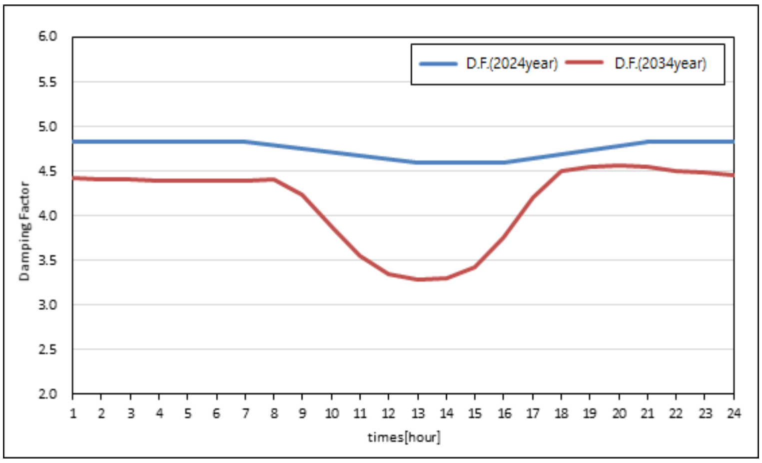


Figure 9. Damping Factor variation by the renewable energy in the power system (2024 and 2034 year)

4. CONCLUSION

The demand curve for the power system would be expected to have the greatest impact on the afternoon hours (8 a.m. to 15:00 p.m.) when new and renewable energy rapidly increases. The problem has been occurred to the grid frequency reached the grid fluctuation reference frequency (±0.2 [Hz]) due to the dropout of the generator at the weekend off-peak load in Korea. Also, if the reference frequency is less than 59.8 [Hz], the power exchange 10% of the total renewable energy would be separated from the system and operated.

Therefore, this could be lead to a problem of a power outage in the domestic power system. It would be important resource to prevent system separation of new and renewable energy by inputting a generator having an inertial force, and to increase system stability and reliability by increasing the system inertia. The inertia force was very low with the input of large-capacity renewable energy in the power system. This could be increased the risk of power failure due to the dropout of the general generator, and it has been expected that the reliability of the power system will be lowered. So, research on a generator will be needed to improve the reliability of the power system.

5. ACKNOWLEDGMENT

This study was supported by the research grant of Wonkwang University in 2021.

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