ディマンドリスポンスを用いた電力システムの構築
Construction of a Power System that utilizes Demand Response

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1. Introduction

In recent years, there has been an increase in the integration of renewable energy sources (RES) such as photovoltaics (PV) into the power grid as a solution to lower CO_2 emissions. However, a high penetration of PV can make the power grid unstable due to intermittency. The output of PV is greatly affected by weather conditions and this can cause fluctuations in the grid frequency. Conventional forms of power generation such as thermal power and pumped storage hydropower are used to maintain the balance of power supply and demand. In Japan, thermal power generation is used to compensate for any changes in output due to PV. As PV penetration increases, however, a more cost-effective and flexible method to keep the power grid stable is needed. Recently, there is a growing interest in the application of demand response (DR) as a method for frequency regulation.[1] This paper will investigate the effectiveness of a power system utilizing DR as a countermeasure to increased PV integration.

2. Research Purpose

The purpose of this research is to propose the construction of a power system using DR as a countermeasure to output and frequency fluctuation due to increased PV integration. By utilizing DR, the power system is expected to have greater flexibility at a lower cost. Furthermore, this can reduce the reliance on using conventional thermal power generation to balance the supply and demand during peak periods. As a result, PV can be used more effectively. In order to investigate the effects of DR on the power system, simulations will be conducted on MATLAB/Simulink using the AGC30 model.

3. AGC30 Model [2]

For this research, the power supply and demand analysis model (AGC30 model) proposed by the Institute of Electrical and Electronics Engineers of Japan (IEEJ) will be used to conduct simulations on MATLAB/Simulink. The AGC30 model is a standard model for conducting load frequency simulations. Figure 1 shows an overview of the AGC30 model.

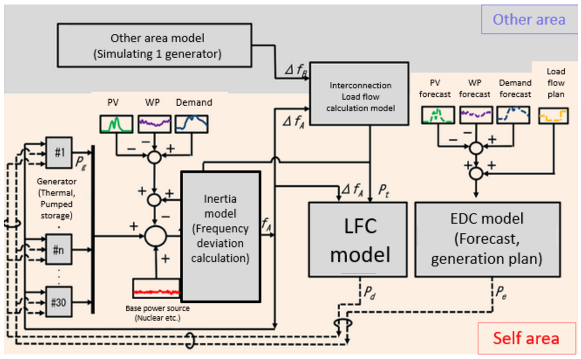

Figure 1 Overview of the AGC30 Model[2]

It consists of 30 generator models along with others such as load frequency control (LFC) and economic dispatch control (EDC) model blocks. This model also includes standard load, PV, and wind power data and is therefore useful for conducting simulations.

4. Simulation
4.1 Simulation Conditions

Based on the standard AGC30 model, a power system model that will reflect the effects of DR will be proposed as shown in figure 2 below.

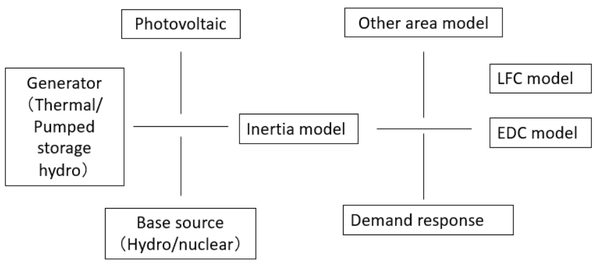

Figure 2 Overview of proposed model

In addition, Table 1 shows a summary of the conditions to be used when conducting the simulations. In this paper, simulations will be conducted on a heavy and light load pattern to simulate peak and off-peak periods. As for RES data, only PV input data will be used for simplicity. Furthermore, a ramp up and down PV pattern will be used to simulate rapid changes in PV output.

Table 1 Simulation Conditions

Setting	Condition
Simulation Period	11 AM – 2 PM (3 hours)
Peak demand	18,000 MW (Heavy load period) / 12,000 MW (Light load period)
PV	Standard ramp up and ramp down data
Generator model	Oil 250 MW / 700 MW
	Coal 700 MW / 1,000 MW
	LNG 200 MW / 700 MW
	GTCC 250 MW
	Pumped storage hydro (Constant/variable speed) 300 MW
Time data	Hydro 3,415MW /Nuclear 1,000 MW

4.2 Results

Figure 2 below shows the forecasted and actual demand and EDC for a time period of 3 hours between 11PM and 2AM.

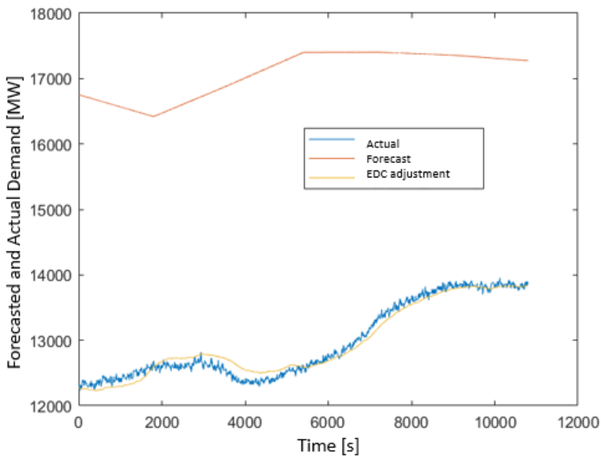

Figure 2 Comparison of forecasted and actual demand

It can be seen that there is a huge gap between the forecasted and actual demand. Even with adjustments with EDC, there is still a constant difference between the forecasted and actual demand. Therefore, additional flexible resources are required as conventional methods are not enough to compensate for sudden and huge changes in the load curve.

Figure 3 shows the supply, demand and PV output for 3-hours during off-peak period. It can be seen that by introducing PV, the supply of power using conventional PV can be reduced. The application of DR also allows the supply to follow the demand curve closer as PV output decreases.

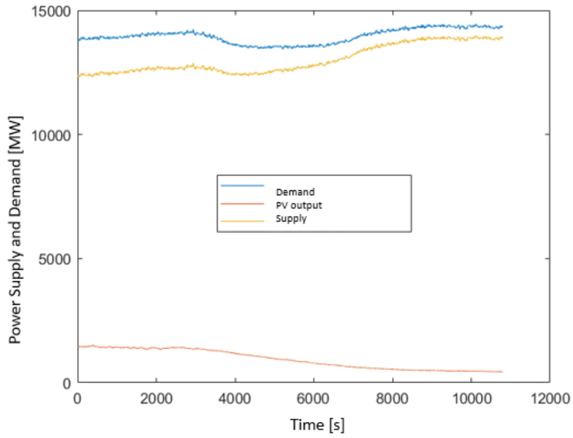

Figure 3 Supply, demand, and PV output

Figure 4 shows the unit cost per generator type showing that generating costs are greatly affected by changes in PV output. There are also running constant running costs in keeping reserve generators in operation.

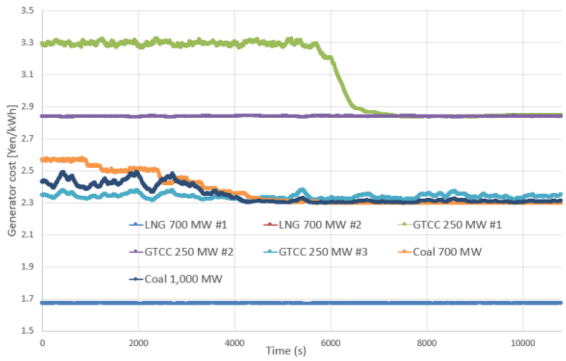

Figure 4 Unit cost per generator

5. Conclusion and Future Works

In this paper, the effect of including DR in a power system was investigated. Instability due to PV can be reduced and a more stable output can be achieved. Furthermore, DR can reduce demand during peak periods, or to increase the load during oversupply of PV. Thus, the increased flexibility provided by DR will allow a higher integration of RES and make them more effective as a main power source. However, only a short time period could be simulated and a longer simulation period is required to further investigate the effectiveness of DR.

References

[1] バーチャルパワープラント(VPP)・ディマンドリスポンス(DR)とは. (2017). 経済産業省 資源エネルギー庁. (2020年12月1日観覧) https://www.enecho.meti.go.jp/category/saving_and_new/advanced_systems/vpp_dr/about.html

[2] AGC30モデルの概要 | 電気学会 電力・エネルギー部門. (n.d.). 一般社団法人電気学会電力・エネルギー. (2020年12月1日観覧) http://denki.iee.jp/pes/?page_id=2009