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A Study of Ancillary Service by Load Fluctuation Analysis in Large Capacity System

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Abstract
Background/Objectives: It has managed the supply power by changing the demand load in the power system. It was necessary to plan power supply and demand for power system stabilization. The Supply power was need to ancillary power for service supply power stability that was improved the power quality.

Methods/Statistical analysis: It was analyzed to secure reserve power by load fluctuation. The analysis method was used statistical analysis that the sigma distribution probability. Power system data was calculated average time by variation rate that has been shown the average load and standard deviation load. The data was shown to using each average value from real-time to 15 [min].

Findings: The load fluctuation was shown by operating large capacity load. It should be corresponding the load fluctuation that was analyzed by reserve power type. Reserve power was used to decrease LOLP (Loss of Load Probability). It was examined power supply stability by reserve power in ancillary service. It could be deduced to improvement that secure reserve power capacity by matched domestic power system.

Improvements/Applications: It should be applied the generator operation, an energy storage system for peak mitigation by technical measures the load fluctuations and to ensure the reserve power.

Keywords: *Power System Load, Fluctuation, Sigma distribution, Frequency regulation operation, Reserve Power.*

1. Introduction

The power system should be managed the supply power due to fluctuate the demand load. The balanced load was monitoring to the frequency in the power system. The frequency has been risen and dropped that the supply power was higher and lower than the demand power. Electrical energy should be controlled by the demand power for ever-changing generation power, because it was difficult of mass storage. Severe frequency fluctuations should be disturbed the power stability (grid collapse, wide blackout) for maintain the $60[\text{Hz}](\pm 0.02[\text{Hz}])$ to match supply and demand power in real-time. Industrial loads have been occupied a percentage less than the general, commercial, and residential power customers. However, industrial load capacity was high the share in total power market. The domestic power system has supplying power by averaging load fluctuation for 15 minutes that the supply power has been depended on the reserve power [1,2].

This paper proposes a method to check the amount of power caused by real-time load fluctuations and to analyze the reserve power due to load fluctuations. It was analyzed the load fluctuation in the power system. It has been shown to analysis the power usage pattern of domestic industrial load [3-6]. The large demand fluctuation was incurred by impairment of frequency fluctuations or power system stability, the rising of electricity cost. The supply power was managed the intermittent load to give effect on adversely influence. The large demand fluctuation in short-term (within 15 minutes) was caused on the results in a system such as frequency fluctuations or safety disturbance and rising cost of power [7-12]. The power system reliability could be considered cost reduction through appeasement methods of load fluctuation large scale power consumer.

2. Methods

The power system was composed of network in generator, transmission, distribution system, and load. It should be closely managed and controlled to balancing power supply and demand at real-time. For power supply side, it has been controlled power capacity by changing power demand that was solved the problems by showing outage and contingency.

2.1. Data of Load fluctuation the power System

It was shown the daily curve in the domestic power system at real-time as shown figure 1. The load fluctuation has been shown that maximum load capacity was 61,728[MW] (at p.m. 11:15:40), and minimum load capacity was 49,011[MW] (at a.m. 3:28:56).

It was function of average power capacity about load fluctuation as shown formula (1).

$$\sum_{i=1}^{n} \frac{\Delta P_i}{n} \tag{1}$$

Here, i is a discrete 1 [sec] interval variable with possible outcomes 1, 2…n . n is 86,400 when it equals to 24[hr] it is 24 X 60 X 60. P is show the load capacity at the interval time.

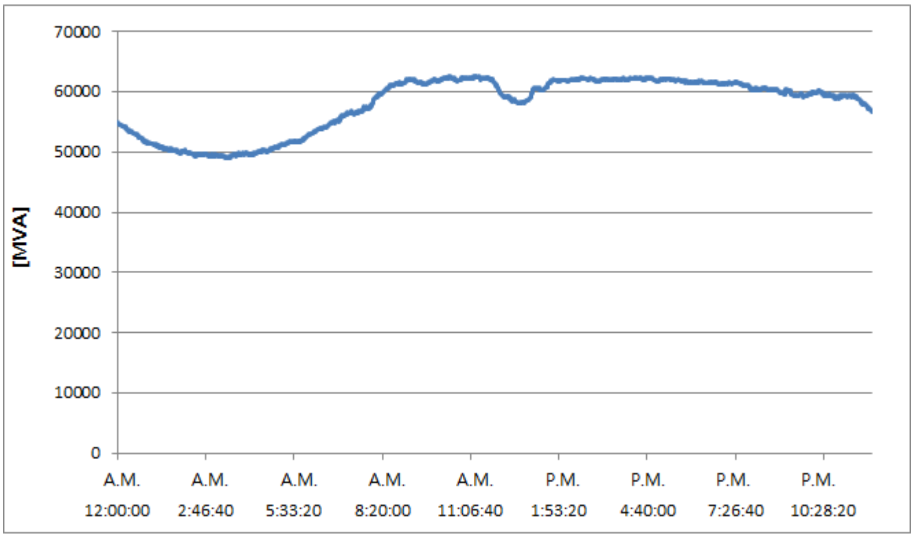

Figure 1. Daily Load Curve in demotic power system

A reserve power capacity has been calculated by average load fluctuation(10[sec], 1[min], 5[min], 15[min]) to reference the real-time daily power load as shown figure 2. It has been shown large fluctuation in average 15[min] load than real-time in load fluctuation. It was decreased the reserve power by using continues load following in GF (Governor Free) reserve. It has been increasingly charge to manage reserve power.

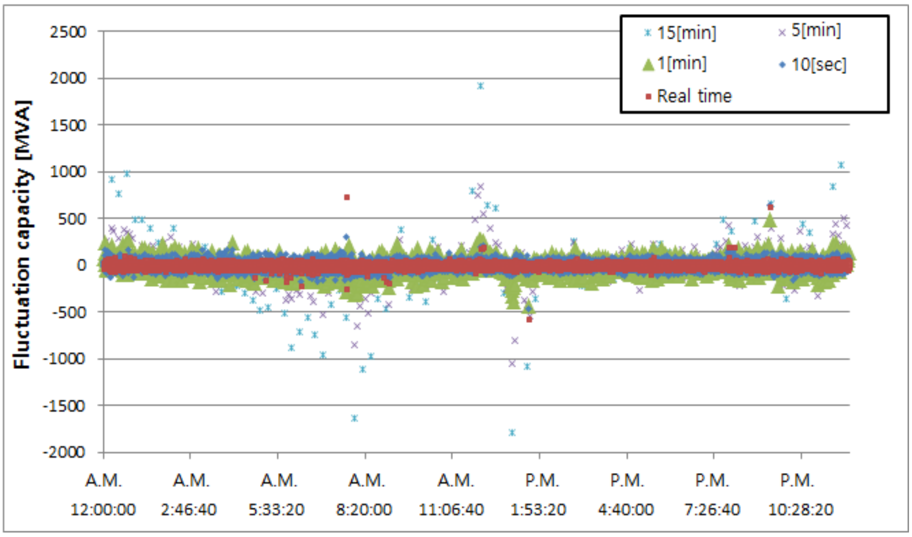

Figure 2. fluctuation calculation by load capacity curve

2.2. Load Fluctuation by using Statistics

A power system fluctuation has been analyzed reserve power by using standard deviation function. It was shown the probability distribution curve by statistical load fluctuation data as shown figure 3 and table 1. A sigma has been used to data rate in distribution curve that 1 sigma was plenty of data rate and 3 sigma was low in data rate. The reserve power was calculated by using distribution curve that was analyzed the statistical load fluctuation capacity.

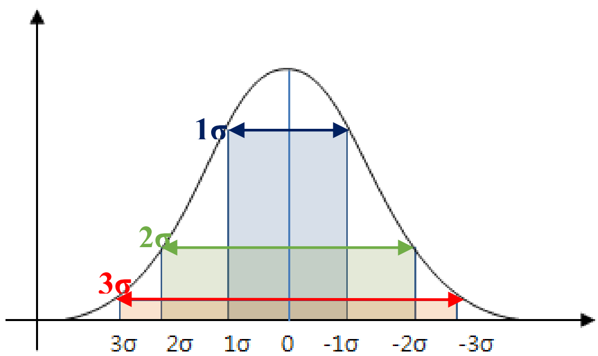

Figure 3. Sigma curve for load fluctuation calculation

Table 1: Probability by load fluctuation data rate in the power system

Rage	Occupancy rate [%]	Escape form probability
μ ± 1σ	68.26%	1/3
μ ± 2σ	95.44%	1/22
μ ± 3σ	99.73%	1/370

It was shown the standard deviation for calculating the load distribution state in load fluctuation as shown formula (2).

$$\bigvee_{i=1}^{n}\left(\frac{P_i - \sum_{i=1}^{n}\frac{\Delta P_i}{n}}{n}\right) \qquad (2)$$

Here, i is a discrete 1 [sec] interval variable with possible outcomes 1, 2…n . n is difference from reserve time.

Load fluctuation has been calculated by reserve time as shown table 2. Reserve time has been made a decision power control time for matching power supply and demand.

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Table 2: Functions of fluctuation calculation by measuring time of the power system load

Reserve time		Load fluctuation	Explain
G.F. Reserve	Real-time	$\bigvee_{i=1}^{24\times60\times60} \Delta P_i$	Daily Fluctuation value of the power system (data number=86,400)
	10[sec]	$\bigvee_{i=1}^{24\times60\times6} \left(\frac{\sum_{j=1}^{10} \Delta P_{ij}}{10}\right)$	Daily Fluctuation value by 10[sec] average of the power system (data number=8,640)
A.G.C. Reserve	1[min]	$\bigvee_{i=1}^{24\times60} \left(\frac{\sum_{j=1}^{60} \Delta P_{ij}}{60}\right)$	Daily Fluctuation value by 1[min] average of the power system (data number=1,440)
	5[min]	$\bigvee_{i=1}^{24\times12} \left(\frac{\sum_{j=1}^{60\times5} \Delta P_{ij}}{300}\right)$	Daily Fluctuation value by 5[min] average of the power system (data number=288)
	15[min]	$\bigvee_{i=1}^{24\times4} \left(\frac{\sum_{j=1}^{60\times15} \Delta P_{ij}}{900}\right)$	Daily Fluctuation value by 15[min] average of the power system (data number=96)

2.3. Analysis of Load Fluctuation

The load fluctuation has been shown to calculate sigma value by using distribution probability in load capacity as shown table 4. The sigma was secured reserve power thought the distribution rage of load fluctuation capacity. The load fluctuation was represented according to the magnitude by 1, 2, and 3 sigma. The load fluctuation would be most certainly analyzed the real-time to secure reserve capacity. The load fluctuation would be showed average 30 [sec] to be changed the sigma level. It has been determined the GF reserve power or the AGC reserve power.

Table 4: Range by load fluctuation of large capacity load

Distribution rate	Average Load Capacity [MW]									
	2[sec]		10[sec]		1[min]		5[min]		15[min]	
1σ	-15.2	15.2	-38	38	-80	78	-192	180	-449	391
2σ	-32.0	32.0	-83	83	-178	176	-456	444	-1129	1071
3σ	-53.0	53.0	-132	132	-206	204	-753	741	-1829	1771

It was shown that was fluctuation distribution curve in the power system as shown figure 4. The fluctuation load capacity was shown the fast-response characteristic for operating GFCM (Governor Free Control Mode). GFCM could be recovered the fluctuation load within 30[sec]. It was matched in occupancy rate of the sigma distribution curve.

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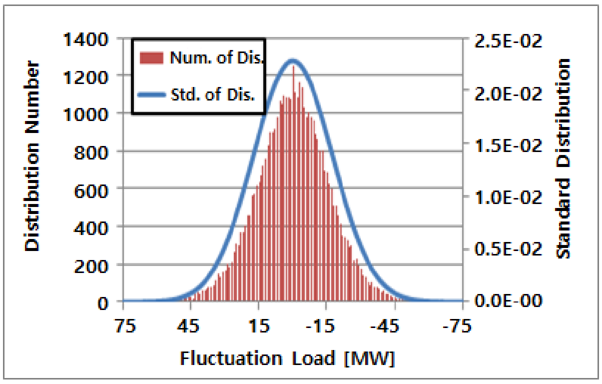
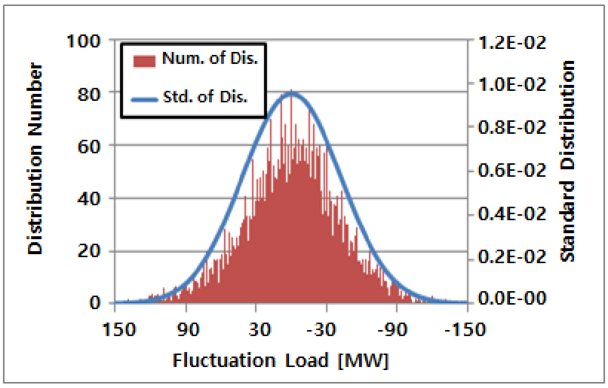


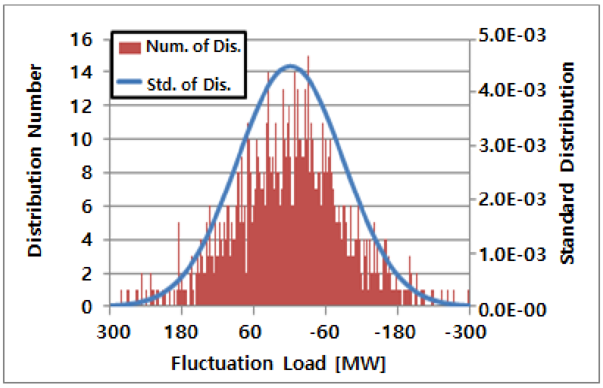
(a) Real-time (2[sec])



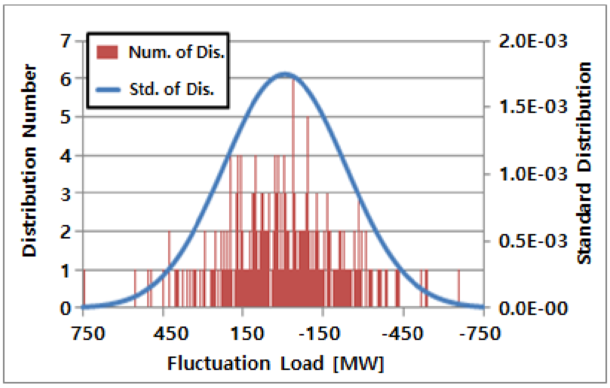
(b) Average 10 [sec]

Figure 4. Load fluctuation distribution curve for securing the GF reserve power

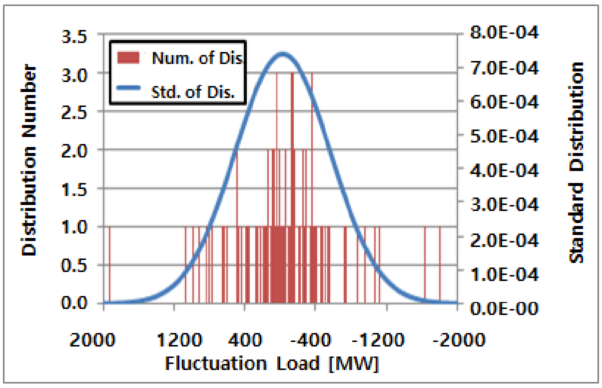
It was shown that was fluctuation distribution curve in the power system as shown figure 5. The fluctuation load capacity was shown the mid-speed response characteristic for operating AGCM (Automation Generator Control Mode). AGCM could be recovered the fluctuation load within 15[min]. It was matched in occupancy rate of the sigma distribution curve.



(a) Average 1[min]



(b) Average 5 [min]



(c) Average 15 [min]

Figure 5. Load fluctuation distribution curve for securing the AGC reserve power

Table 3: Reserve Power by average time of the power system load.

Rage	G.F. reserve [MW]		A.G.C. reserve [MW]		
	Real-time	Avg. 10[sec]	Avg. 1[min]	Avg. 5[min]	Avg. 15[min]
1σ (68.2 %)	-15.2 ~ 15.2	-38 ~ +38	-80 ~ +78	-192 ~ +180	-449 ~ +391
2σ (95.4 %)	-32 ~ +32	-83 ~ +83	-178 ~ +176	-456 ~ +444	-1129 ~ +1071
3σ (99.6 %)	-53 ~ +53	-132 ~ +132	-206 ~ +204	-753 ~ +741	-1829 ~ +1771
Need to Generation	106 (-)	264 (2.5 times)	410 (4.9 times)	1494 (13.5 times)	3600 (32 times)

4. Conclusion

This paper proposed a decision economic reserve power capacity to use probability distribution function. It could be used as a policy decision data on the improvement of power system voltage stability in the technical side, and it could be secure system long term stability by reflecting the transmission and facility plan. On the economic side, it could be improved the reliability by improving the voltage stability, reduced the power supply cost, allocated the capital investment defiantly, and minimized the damage of the national economy by the wide power outage. So, the reserve power has been expected to improve reliability of power system with spinning reserve power with fast response speed in power system. The domestic reserve power has been secured with more electricity than load fluctuations. Therefore, it is necessary to analyze using the suggested method for realistic reflection.

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