IMPACT STATEMENT OF DISTRIBUTION NETWORK BY FLUCTUATION OF PV SYSTEM OUTPUT BY USING FREQUENCY ANALYSIS

N. Kawasaki[1], T. Oozeki[1], K. Otani[2], K. Kitamura[3], H. Sugihara[4], S. Nishikawa[5] and K.Kurokawa[1]
[1]Tokyo University of Agriculture and Technology, 2-24-16 Naka-cho, Koganei, Tokyo, email: norihiro@cc.tuat.ac.jp
[2]National Institute of Advanced Industrial Science and Technology (AIST), AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki, Japan , email: k.otani@aist.go.jp
[3]MEIDENSHA CORPORATION, Riverside Building, 36-2, Nihonbashi Hakozakicho, Chuo-Ku, Tokyo, Japan , email: kitamura-k@honsha.meidensha.co.jp
[4]Kandenko Co., Ltd,, 4-8-33 Shibaura Minato-ku Tokyo, Japan , email: sugihara-h01@kandenko.co.jp
[5]Nihon University, 1-8-14 Kanda Surugadai Chiyoda-ku Tokyo, Japan , email: nishikawa@ele.cst.nihon-u.ac.jp

ABSTRACT: An output of PV systems has a short-term fluctuation due to weather fluctuation. With high connection densities of PV system in the distribution network, this might cause to degrade electric power quality e.g. voltage fluctuation and frequency variation. Recently, rapid growing end expanding of the PV systems in the electric power systems make a large benefit to reduce environmental problems. Therefore, the necessity for evaluating the influence that fluctuation of PV system output exerts on the distribution network has risen. In this paper, the impact statement method of distribution network by the fluctuation of PV system output by using frequency analysis is described. The impact statement of distribution network by the fluctuation of PV system could be analyzed in every frequency bands by this evaluation method.
Keywords: Grid-Connected, PV System, Quality

1 INTRODUCTION

An output of PV systems has a short-term fluctuation due to weather fluctuation. With high connection densities of PV system in the distribution network, this might cause to degrade electric power quality e.g. voltage fluctuation and frequency variation. Recently, rapid growing end expanding of the PV systems in the electric power systems make a large benefit to reduce environmental problems. Therefore, the necessity for evaluating the influence that fluctuation of PV system output exerts on the distribution network has risen.

An important study of the fluctuation analysis of grid-connected PV systems has already been approached by using wavelet transform [1]. This paper describes a definition of the Fluctuation Power and Energy Indices by using wavelet power spectrum. This study has developed simulation method of the fluctuation analysis of grid-connected PV systems in the distribution network. Generally, actual measurement data on many sites cannot be obtained easily.

In Japan, the new national R&D project on PV system (Demonstrative Research on Grid-connection of Clustered Photovoltaic Power Generation Systems) has been start since 2002 [2]. The target of this project is to solve technical problems such as restriction of PV system output, higher harmonics and islanding operation where PV systems are clustered in a residential district. In this project, about 510 grid-connected PV systems with battery installed at residential houses and are monitored at all times. This study is the smoothing effect ([3], [4]) of fluctuation of irradiation and PV output, is performed by part of this project. The smoothing effect is natural phenomenon that smoothes fluctuation of irradiation in a certain area. Especially, fluctuation of irradiation by movement of cloud is smoothed.

Currently, we clarified that smoothed magnitude and speed of fluctuation by the smoothing effect. This effect has the advantage for distribution network. Next phase, it is necessary to estimate impact statement of distribution network with the fluctuation of PV system output.

In this paper, the impact statement method of distribution network by the fluctuation of PV system output by using data obtained in real system is described.

2 APPROACH

Figure 1 shows the electric power flow of a grid-connected PV system without battery, is composed of power conditioner system (PCS: A) power, load supply, and grid power (C). C is decided by A and B; C=A–B. The impact statement of distribution network by the fluctuation of PV system output needs to analyze the relation between A and C. Additionally, to evaluate the electric power quality, it is necessary to analyze them for each cycle of the fluctuation. Therefore, FFT (Fast Fourier Transform) was used for the analysis, waveforms was separated by using it like the filter for each cycle of fluctuation.

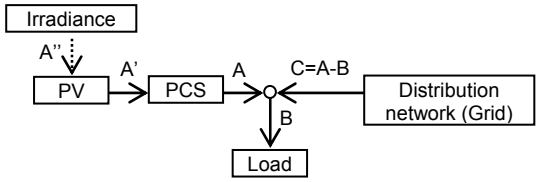


Figure 1: Power flow of a grid-connected PV system (A: PCS power, B: Load supply, C: Grid power)

Figure 2 shows the estimation method of impact statement of distribution network with the fluctuation of PV system output, is composed of data input, filter, and correlation. The division of the frequency domain used octave division; logarithmic scale of frequency axis is divided equally (see Table I). This division method is especially easy to analyze for low frequency domain. IFFT (Inverse FFT) transforms Fourier coefficient separated by octave division to time domain for each level. Figure 3 shows separated result by using this method.

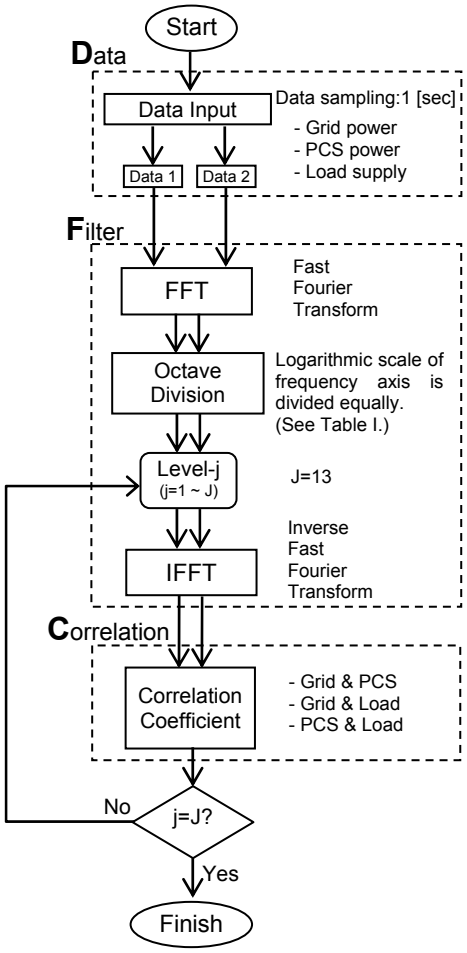
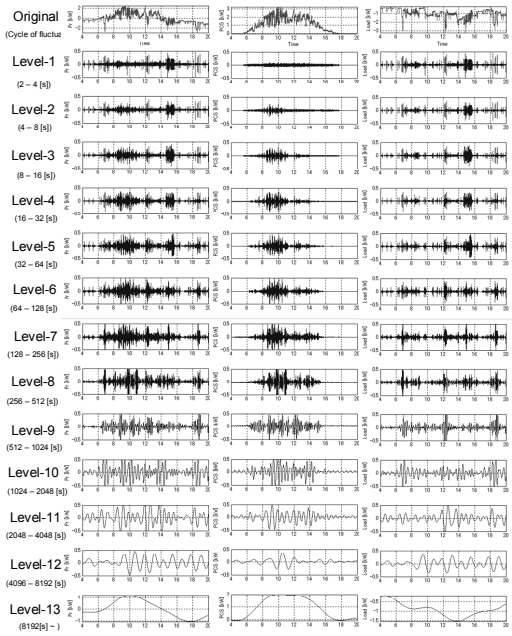


Figure 2: Analysis of flow chart



(a) Grid power (b) PCS power (c) Load supply

Figure 3: Separated waveforms for each level (21 August 2004)

Then, correlation of two data items of Fig 3 is analyzed for each level. The combinations of the correlations are "grid power and PCS power", "grid power and load supply" and "PCS power and load supply". Correlation coefficient of between grid power and PCS power means impact statement of distribution network by the fluctuation of PV system output.

Level - j	1 cycle of fluctuation ($2^{j} \sim 2^{j+1}$ [sec])		
1	2	~	4
2	4	~	8
3	8	~	16
4	16	~	32
5	32	~	64 (about 1 [min])
6	64	~	128
7	128	~	256
8	256	~	512
9	512	~	1024
10	1024	~	2048
11	2048	~	4048 (about 1 [hour])
12	4096	~	8192
13	8192	~	

Table I: Relationship between level and 1 cycle of fluctuation

3 DATA USED IN ANALYSIS

The demonstrative test site of this project is "Pal Town, Zyosai no mori" in Ota city, Gunma prefecture. This site is a new residential section. Average area of each division is about 250 m^2. More than 200 residential PV systems are already installed on top of the roofs and connected to the power grid in less than 1km^2 area. All of the installed PV systems are equipped with measurement system [5]. Voltages, currents and phases are being measured every second at the points of PV array output, PCS output and connecting point to the power grid. Irradiance, ambient temperature, wind direction and wind speed are also measured every second.

Data used in analysis, active power of grid or PCS or load, has been recorded by one second sampling. Figure 4 shows irradiation pattern of analyzed days, are chosen from a large variety of pattern of irradiation. Furthermore, heavy load site and light load site on these days were analyzed.

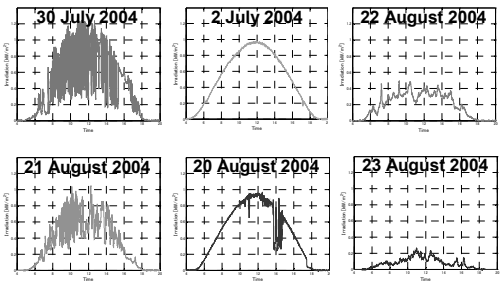


Figure 4: Irradiation pattern of analyzed days

4 RESULT

A correlation analysis was done on grid power and PCS power for the impact statement of distribution network by fluctuation of PV output. Furthermore, to supplement it, a correlation analysis was done on grid power and load supply, PCS power and load supply. The condition of the analysis is as follows.

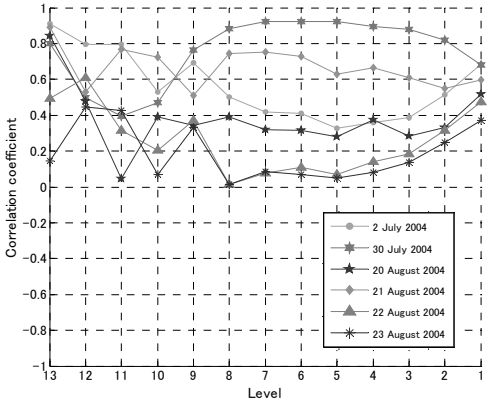
- Days of 6 irradiation patterns (see Figure 4.)
- Light load site and heavy load site
- 3 combinations of correlations (grid power and PCS power, grid power and load supply, PSC power and load supply)

Figure 5 shows results of light load site, and Figure 6 shows results of heavy load site. The following is to understand from this result.

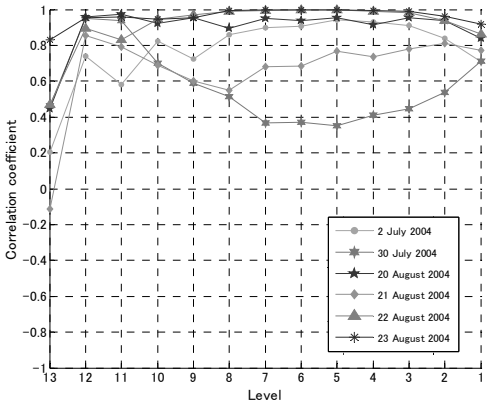
- Correlation between grid power and PCS power:
  Light load site:
  Correlation coefficients from level-1 to 8 depend on magnitude of fluctuation of irradiation. It is necessary to pay attention to these frequency bands.
  Heavy load site:
  Correlation coefficients from level-1 to 3 are small. Correlation coefficients from level-4 to 8 depend on magnitude of fluctuation of irradiation. In this case, it means that the influence of load on grid is big for correlation coefficients from level-1 to 3.

- Correlation between grid power and load supply:
  Light load site:
  The correlation of each level is strong, excluding fluctuation day (7/30 and 8/21). This means that the influence of load on grid is big.
  Heavy load site:
  At low irradiation days, the correlation of each level is strong. However, the correlation from level-4 to 9 depends on magnitude of fluctuation of irradiation. This means that the influence of PCS power on grid is big at fluctuation days.

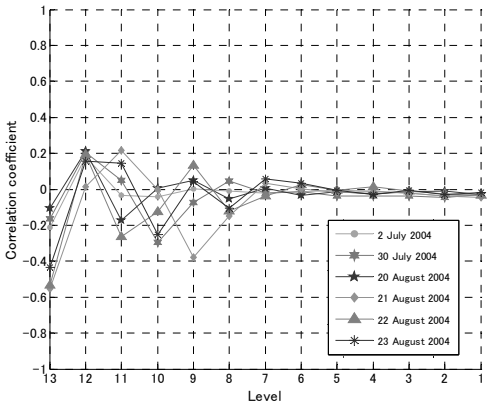
- Correlation between PCS power and load supply:
  Light load site:
  Basically, PCS and load is non correlation. However, correlation coefficient of level-13 is inverse correlation. This means that power generation and consumption are opposite relation.
  Heavy load site:
  Correlation coefficients from level-1 to 9 are small. Correlation coefficients from level-10 to 12 are instability. Correlation coefficient of level-13 is inverse correlation. In this case, relations between PCS power and load supply are poor.



(a) Correlation coefficient between grid power and PCS power

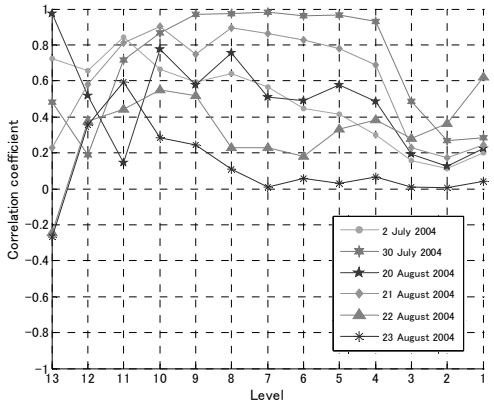


(b) Correlation coefficient between grid power and load supply

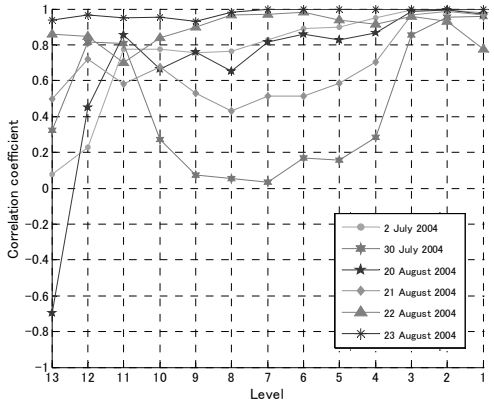


(c) Correlation coefficient between PCS power and load supply

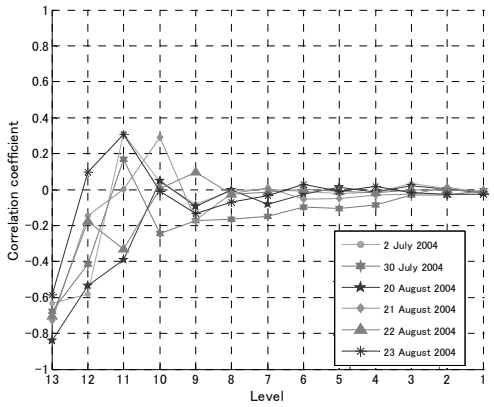
Figure 5: Correlation coefficient for each level (light load site)



(a) Correlation coefficient between grid power and PCS power



(b) Correlation coefficient between grid power and load supply



(c) Correlation coefficient between PCS power and load supply

Figure 6: Correlation coefficient for each level (heavy load site)

5 CONCLUSION

The influence of the fluctuation of PV system could be analyzed in every frequency bands by this evaluation method. A difference due to the weather almost appeared in the influence from the PV system in the level of 3 - 8 clearly as that result. In other words, you must know about the fluctuation in these domains in detail. This result is only a part of the actual phenomenon. In the future, result of analysis will be increased, and we will want to analyze statistically. Moreover, you must make short time interval which correlation is analyzed in detail.

Acknowledgments

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