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A RESEARCH OF BASIC ENERGY REDUCTION APPROACH USING PV POWER SMOOTHING EV STORAGE SYSTEM AND LED SIMPLE CIRCUIT FOR CREATE GREEN INNOVATION

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Abstract

In general, Light Emitting Diode (LED) is low power consumption, and Photovoltaic (PV) generation of Renewable Energy is effective as energy creation. However, LED applications have a problem of LED Circuit Radiation Noise and PV generation applications have a problem of the Output Power fluctuation in the weather. This paper will be proposed as an especial approach of the energy reduction to contribute to the realization of the low carbon society in the world. In this research, without using Common Mode Choke (CMC) Noise Cut filter, the Radiation Noise reduction result in World Standard Guideline by the selection of a simple circuit of the most effective LED lighting of various power reduction methods have been confirmed by the examinations. Additionally, in order to investigate the lighting specification, the simple Lighting evaluation equipment has been developed. As an energy fluctuation reduction research, the new control system of the PV fluctuation electric power using EV battery charge-discharge electric power that is able to be easily connected with a Power Conditioning System (PCS) input is proposed. A simulation result using the actual PV generator output data is provided to confirm the effectiveness of Simple Moving Average (SMA) method. Moreover, the outline of a new large area monitoring control GIS system for the implementation of the PV generator power prognostication without the weather estimation is introduced.

Keywords: LED, Renewable energy, EV storage, PV power generation, PCS, Radiation noise reduction, PV power fluctuation suppression, GIS.

Abbreviations

CISPR	International special committee on radio interference
CMC	Common mode choke
GIS	Geographical information system
GOJ	Government of Japan
IEC	International electro technical commission
IPCC	Intergovernmental panel on climate change
ISO	International organization for standardization
ITU	International tele communication union
LED	Light emitting diode
LFC	Loading frequent capacity
PCS	Power conditioning system
SMA	Simple moving average

1. Introduction

After Industrial Revolution happened in between the 18th and 19th centuries, the world has entered in the era of mass energy consumption from fossil fuels. With the mass consumption of fossil fuels, global warming caused by CO_2 emission has become a big problem. Intergovernmental Panel on Climate Change (IPCC) has reported average temperature of the earth rose 0.74 degrees in the 100 year period from 1906 to 2006. Also, oil, coal, natural gas is finite and the reserve-production ratio in 2009 is said to be 46, 119, 63 years [1]. Exhaustion issue of fossil fuels has become a problem. In addition, Japan is poor of resources and relies on oil import 98%.

Therefore, the ensuring of domestic power energy has become an important issue [2]. In recent Japan, to be stopping the nuclear power generation since the Great East Japan Earthquake, the base load supply is insufficient. The shortage of power supply has been covered by thermal power generation. However, in the thermal power generation, the fossil fuels are basically used. It becomes the cause of CO_2 emissions and spurs the problem of fossil fuels depletion and global warming inflation. Thus, the spread of a clean alternative energy that does not depend on fossil fuels is important. To correspond to energy problems, Government of Japan (GOJ) is promoting the spread of renewable energy. GOJ has put into the consideration “feed in tariff for renewable energy” as from July 1, 2012. There are (1) solar energy, (2) wind energy, (3) geothermal energy, (4) solar thermal energy, (5) hydro energy, (6) heat energy in atmosphere, heat energy that exists in nature, (7) biomass energy (except the fossil fuels) in the renewable energy [3].

Among the renewable energy generation, because PV has some advantages in comparison with other renewable energy sources the spread of PV is particularly promoted. For example, PV has no locational restrictions, no moving parts such as turbines and generators in the device and no noise in operation. In addition, it is easy to maintain and inspect the PV system. As specific goals of promoting PV, GOJ has set a target in July 2008 to introduce PV of 14 GW of about 10 times higher than the 2005 fiscal year by the 2020 fiscal year and 53 GW of about 40 times higher than the 2005 fiscal year by the 2030 fiscal year. Also, GOJ has revised the target upward of introducing PV of 28 GW of about 20 times higher than the 2005 fiscal year by the 2020 fiscal year [4]. However, there is a major problem in PV, that is, PV is an unstable power source because output of PV fluctuates with amount of solar radiation. Thus, introducing a large amount of PVs disturbs the balance of the electric power supply and demand. As a result the stable power supply operation will be interrupted occasionally. According to the Bureau of Statistics, total number of single-family houses in Japan in 2008 is approximately 50 million [5]. Among that, there will be some houses that cannot be installed PV because the structure of the roof is weak or the orientation of the roof does not fit. Now, it is assumed that there are about 20 million houses that can install the PV. If these houses have PV of 4 kW, total power will be about 80 GW. This power is a value of half of 170 GW~ 180 GW which corresponds to the higher power demand of August [4]. Thus, the quantitative potential of residential PV is very large. In addition, because the automobile industry works toward the low-carbon society, focuses are going on the EV as a clean technology. As a clean technology, the EV was brought to the market in many times since the automobile became commonly used. However, the EV doesn't spread in earnest level yet due to several reasons such as low mileage, high prices of the EV, short battery life, heavy and bulky and so on. On the other hand, the battery technology is leading to a revaluation after the practical usage of lithium-ion battery. Such as: the commuter type EV came to market, upgrading of the hybrid technology and the expected plug-in hybrid technology [6, 7].

In 2009, on Japanese household, an important research about the recognition of energy consumption and the reality has been reported. As for the Japanese recognition of household energy consumption, the energy consumption has been informed that Heating is 40% and Cooling is 30%. And, Cooling and Heating shows energy consumption recognition of over 70% on Japanese household. However, in the reality energy consumption of actual investigation, the energy consumption of Heating and Cooling decreases by 41% and becomes 29%. On the other hand, the energy consumption of lightings and household electric equipment increases by 23% and becomes 37% [8].

The energy consumption of the house-hold electric equipment is guessed to increasing it because a refrigerator, a washing machine, an electric water heater, and the jar, etc. are electric equipment of a large electric power in the Japanese household. In addition, the amount of an integrated electric power shows the tendency to increase because the fluorescent lamp and the incandescent lamp of the lighting are always used at home because the power saving lighting equipment such as Light Emitting Diode (LED) is not applied in 2009 yet. Light Emitting Diodes (LEDs) contain solid state technology made in Silicon Valley using similar technologies that are used in the latest microprocessors. These solid state devices have no moving parts, no fragile glass environments, no mercury, no toxic gasses, and no filament. There is nothing to break, rupture, shatter, leak, or contaminate. They are playing a significant role in energy saving policy. Developing policy must be envisaged in order to reduce impact on environment and energy consumption without sacrificing an important part of economic growth. The solid state nature of LEDs makes them extremely rugged and durable an excellent choice for applications where reliability and dependability are paramount. Moreover, the LED lighting is a power saving equipment that becomes the electric power of 1/10 compared with the halogen lamp. Therefore, in Japan, the substitution from the halogen lamp to the LED lighting is promoted for the reduction of power consumption [9].

In this paper, the electromagnetic radiation problem of EMC etc. by the switching control of the high frequency occurs, the LED equipment proposes the Radiation Noise guideline from the experiment result with the LED circuit that doesn't use the noise filter by selecting the best circuit because it is spear equipment, and it proposes to conform. And, residential PV and EV are assumed. The goal of this research is to use residential PV as a stable power supply generation when a large amount of PV has been introduced in the power system. Specifically, in this paper, it is intended to evaluate a system for suppressing the fluctuation of output from PV by using EV and supplying a stable power to the electric system [10].

2. The Basic Energy Reduction Approach

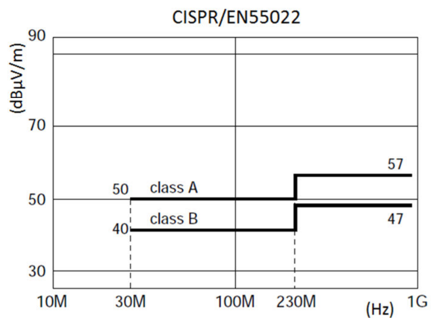
2.1. LED circuit radiation noise problem

2.1.1. World standards of radiation noise guideline

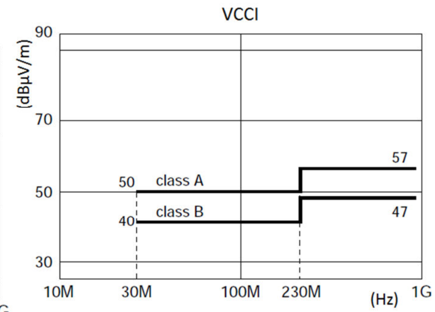
In Table 1, World Standards Radiation Noise Guideline is introduced the standard specification of EU, USA, Japan. LED can be decreasing the electric power of lighting. In Japan, LED became the main source of Lighting. However, there is the issue of the radiation noise because LED circuits operate by the high frequency switching. Therefore, the noise restriction of the device is done all over the world. In the world, a variety of Radiation Noise Standards exists as in Fig. 1 [11]. The main international discussion organisation concerning EMC is IEC (International Electro technical Commission), ITU (International Tele communication Union), ISO (International Organization for Standardization), and CISPR (International special committee on radio interference) and so on. Figure 1(d) shows that IEC60945 of the noise restriction is the severest, and is 24dB around 150 kHz. In radiation noise standard, 40dB is very hard. However, in IEC60945, there is 24dB. And it is less than Class B Noise guideline level.

Table 1. World Standards Radiation Noise Guideline.

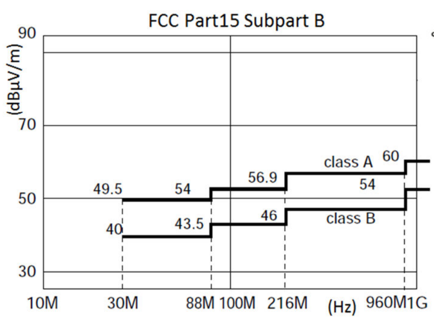
Standard			Notes
EU	EN	European Norm	The EN standards were established as unified standards in Europe. CE mark is stuck in the product that passed EMC directive.
Japan	VCCI	Voluntary Control Council for Interference by Information Technology Equipment	According to the CISPR Recommendation, in 1985 the industry Self-imposed restraint.
USA	FCC	Federal Communications Commission	Standard of the U.S. military. It is referred in the field where the standard is not decided worldwide.
	ANSI	American National Standards Institute	
	MIL	Military Standard	



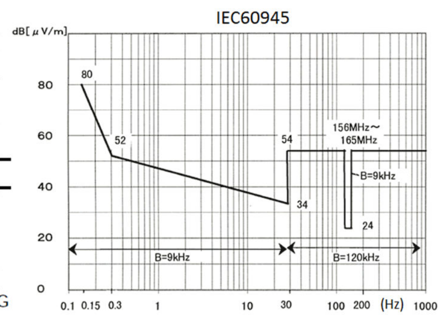
(a) CISPR/EN55022 Standards.



(b). VCCI Standards.



(c) FCC Standards.

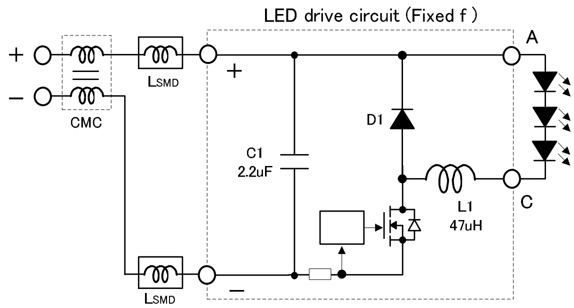


(d) IEC60945 Standards.

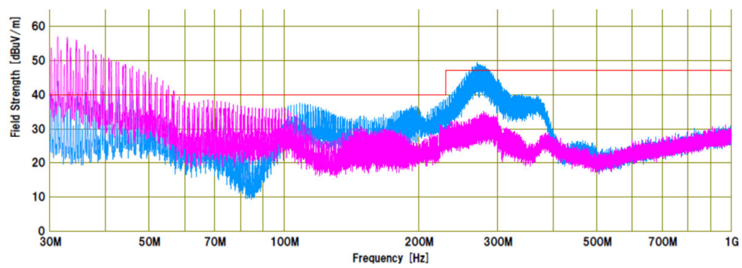
Fig. 1. Radiation Noise Standards [11].

2.1.2. Radiation noise specification of simple LED circuits

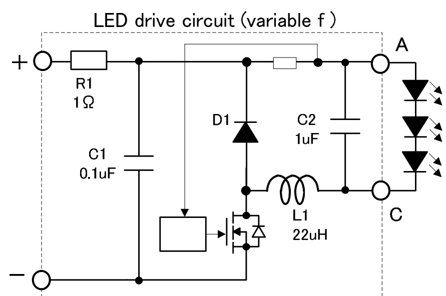
To confirm the noise environment, Fig. 2 shows each simple LED circuits and Radiation Noise data. In these figures, the low noise waveform and the LED circuits of constant current control are shown and described. From the results of Figs. 2(a) and b), even if the Noise Filter equipment is made to adjust, they cannot pass the radiation noise guideline of CISPR or EN55022 Class B in 0.36A circuit. In another 0.36 A circuit of Figs. 2(c) and (d), it shows that passed the radiation noise guideline of CISPR or EN55022 Class B, but cannot be passed the IEC60945 Radiation Noise guideline without Noise Filter devices. This means that the best circuit has to apply to it. And, on the contrary, it means that a circuit with few parts is applicable if the best choice of the LED circuit can be performed. In Fig. 2(e), from result of the optimized circuit, it has confirmed that can pass the hardest guideline in IEC60945. In Fig. 2(g), from Background Radiation Noise data without LED circuit, it has shown that the LED circuit type 3 is equal to IEC60945. Therefore, it was able to prove that Radiation Noise guideline was satisfied by a simple circuit of the best device selection without Noise Filter.



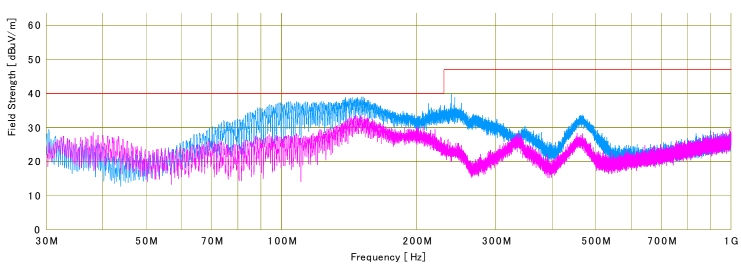
(a) LED Circuit Type 1 Configuration of the N-side Constant Current Control.



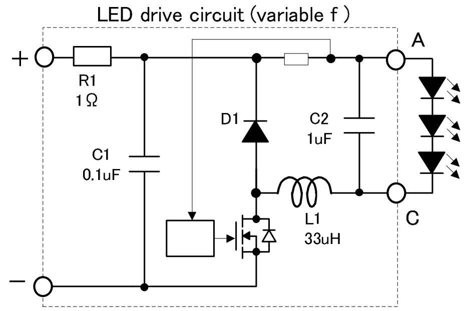
(b) Radiation Noise Data of LED Circuit Type 1 [30V, 360mA].



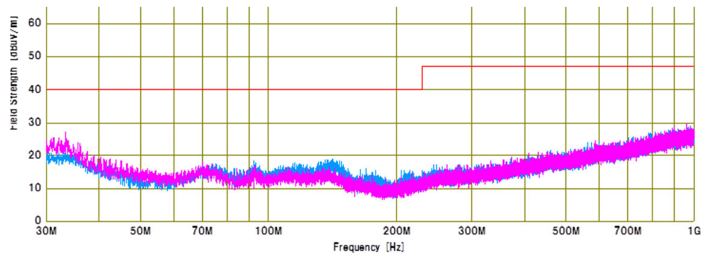
(c) LED Circuit Type 2 Configuration of the P-side Constant Current Control.



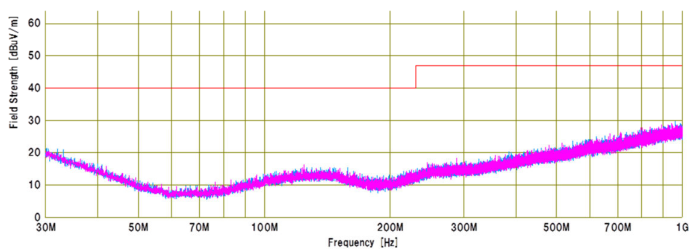
(d) Radiation Noise Data of LED Circuit Type 2 [30V, 360mA].



(e) LED Circuit Type 3 Configuration of the P-side Constant Current Control.



(f) Radiation Noise Data of LED Circuit Type 3 [30V, 500mA].

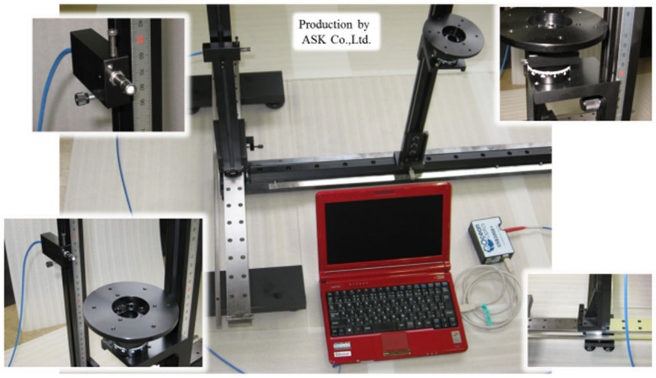


(g) Background Radiation Noise Data [without LED Circuit].

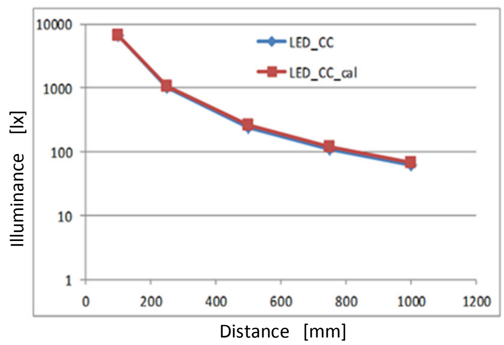
Fig. 2. Simple LED Circuits and Radiation Noise Data.

2.1.3. Experimental unit to confirm LED circuits lighting spectrum

The optimized LED circuit has to confirm LED Lighting spectrum specification. In Fig. 3(a), the developed simple experimental unit is shown. This unit is composed of Cosine Corrector, Pedestal to install LED, and Spectroscope to measure lighting spectrum. PC displays the measurement data, and to analyze lighting spectrum data, the system software is installed in PC. In Fig. 3(b), Lighting spectrum of the low specification equipment and the high specification equipment is compared. LED_CC_cal is the theory calculation result, and LED_CC is the measurement result by this Experimentation unit. The distribution light attenuates in proportion to the distance. However, using the measurement result in the experimental unit, the same correlation as the theory value was shown. Though this experimental unit has investigated with a simple and a low specification device, we were able to obtain the great result that shows the same correlation as the theory value using the developed LED test equipment.



(a) Developed Experimental Unit.



(b) Examination of the Experimental Unit.

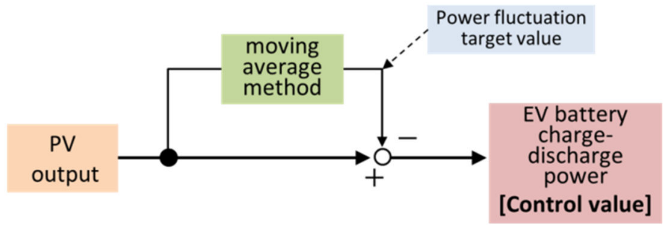
Fig. 3. LED Spectrum Analysis.

2.2. PV fluctuation reduction in power system

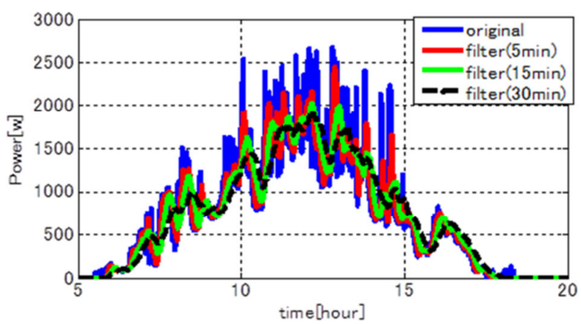
In Japan, photovoltaic generator is promoted as most effective system in natural power sources. However, it is known well that electric power fluctuations occur due to weather conditions. Furthermore, when a large amount of PV has been introduced in the power system, electric power fluctuation may generate the frequency fluctuation and voltage fluctuation of the power system. According to the Bureau of Statistics, the total number of houses in Japan in 2008 is approximately 57 million and it is about 50 million houses with exception the empty houses. As a result the stable power supply operation will be interrupted occasionally. To overcome these issues, the system in this research is described [12]. When using the simple moving average (SMA) method for PV generation output, PV generator fluctuation suppression method and the simulation result of electric power fluctuation has shown as in Figs. 4(a) and (b). In the SMA method, the reference for station output at "k-th" control interval ($P^{*}_{PCC}(k)$) is set to the simple moving average (sampling time is 1[s], averaging time is T_{MA}[s]) of P_{PV} as Eq. (1).

$$P^*{}_{PCC}(k) = \frac{1}{T_{MA}} \sum_{t=1}^{T_{MA}} P_{PV}(k-i) \quad (1)$$

Longer T_{MA} makes the short-term fluctuation of $P^*{}_{PCC}$ smaller, however, it also elongates the time delay of $P^*{}_{PCC}$ to P_{PV}. Longer time delay requires larger P_{BAT}. As a result, too long averaging time increases the risk of power capacity violation and deteriorates the fluctuation suppression performance.



(a) Suppression Method.



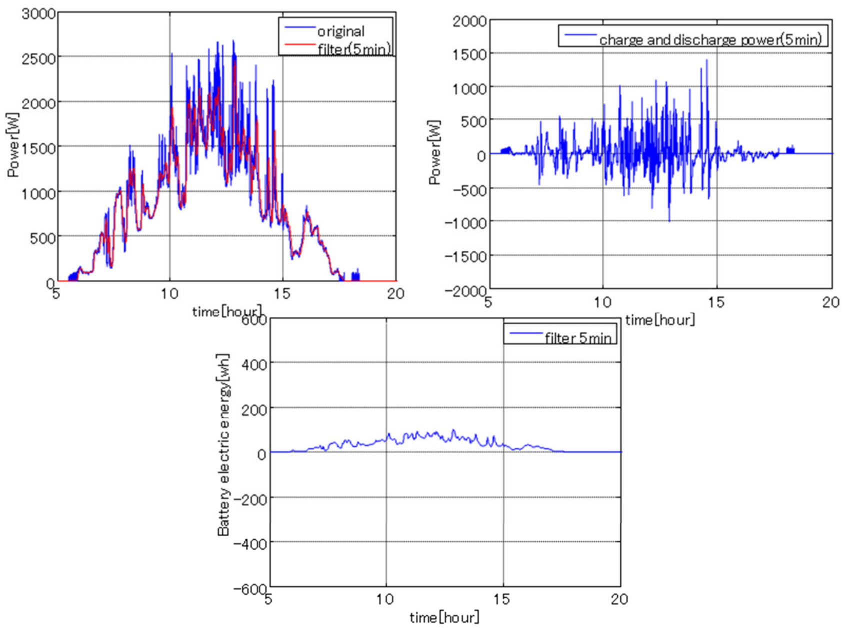
(b) Simulation.

Fig. 4. PV Generator Fluctuation Suppression Method and Simulation.

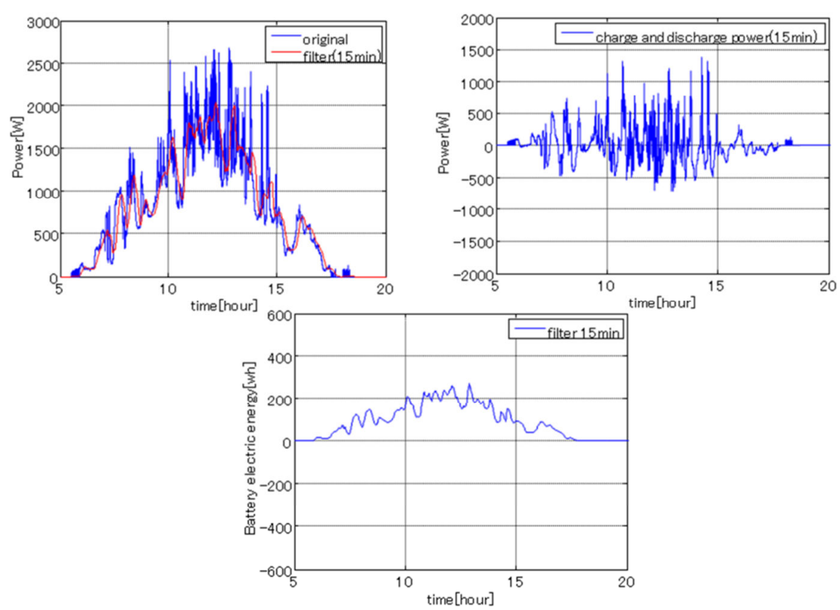
2.3. Result and discussion for PV fluctuation reduction system

When the photovoltaic generator fluctuation suppression method was used, 5 minutes, 15 minutes, and 30 minutes simple moving average control simulations waveform using the actual PV power output are shown in Figs. 5(a), (b), and (c).

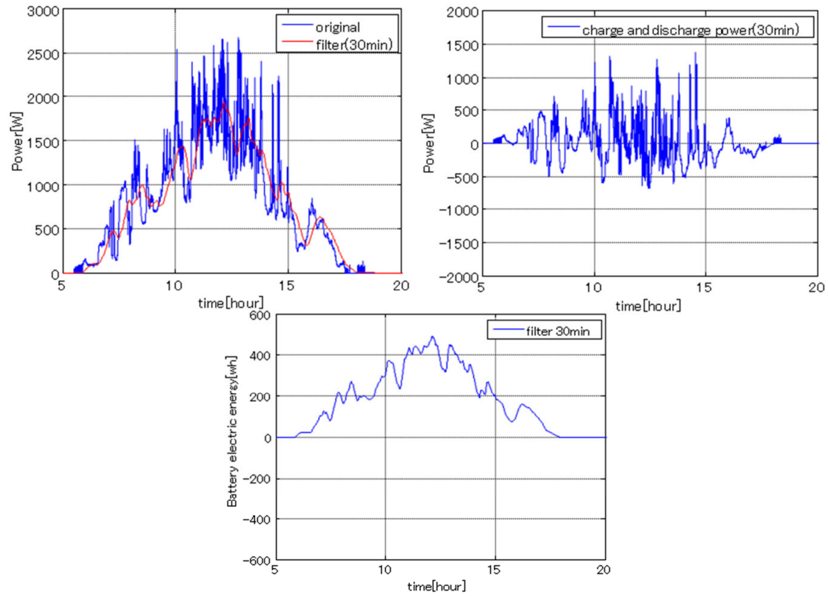
Table 2 shows the battery storage power value of the Simple Moving-Average method. The 15 minutes Simple Moving-Average method is the best so that the data of the moving average can reduce the power fluctuation for 30 minutes as understood from the PV power generation and the simple moving average data of Fig. 5. However, The Battery Power value is increasing. A large value for this battery power has the possibility of influencing the battery longevity. It is guessed to the amount of the battery power that the method of the simple moving average is the most suitable for 15 minutes when the influence is a little because there is little difference from the amount of the electrical charge and discharge maximum power of the method of the moving average for the method of the moving average for 15 minutes and 30 minutes.



(a) 5 Minutes.



(b) 15 Minutes.



(c) 30 Minutes.

Fig. 5. SMA Method Data [Cloudy Day 6/29/2012].

Table 2. Comparison of Moving-Average Simulation [Cloudy Day 6/29/2012].

Moving-Average control		5 minutes	15 minutes	30 minutes
Charge-Discharge	Charge	1460 W	1386 W	1380 W
Max. Power Value	Discharge	1026 W	718 W	681 W
Battery Power value	Max.	**104 Wh**	**270 Wh**	**493 Wh**
	Min. [10^(-12)]	-1.1 Wh	-1.2 Wh	-3.6 Wh

In Fig. 6, to apply the photovoltaic generator fluctuation suppression system, with using DC voltage model of the system, there is a general PV system consisting of a power conditioner and solar cell. The system is constructed by connecting a storage battery of EV through 2-way bidirectional DC/DC converter to control the power in this PV system. In this system, it is very important to consider the fluctuation suppression method of PV output and the value of required charging and discharging power to determine the specifications of the bidirectional DC/DC converter. In this research, moving average method is used as a method for suppressing the fluctuation of PV output. Charging and discharging power of the battery is determined by the difference between actual PV output value and target value set by the moving average method. PV output fluctuation suppression waveform of one day is shown in Fig. 6. The required charging and discharging power value for determining the specifications of the bidirectional DC/DC converter was evaluated using the power data for one year of 2.88 kW PV which is installed in Kyushu Institute of Technology (Kyutech). As a result, it is considered that if there is a charging and discharging power of

1.0-1.2 kW, it is sufficiently possible to suppress the fluctuations of PV output in a day when PV output is relatively large [12, 13].

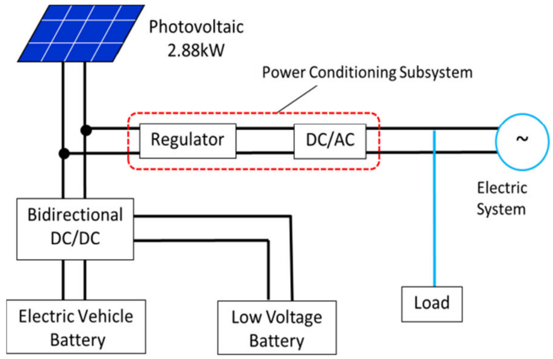


Fig. 6. Outline of the Power Supply System Model.

2.4. Estimation approach of photovoltaic generation

As for the photovoltaic generation, it is known the power fluctuation will be generated according to the weather well. For this reason, even if it performs a control which carried out the moving average estimation of the PV electric power, the control delay of fluctuation suppression is always generated. Such a fluctuation suppression control tends to be used with almost all the PV power generation controls. However, if the sunlight energy density which occurs in a solar panel could be observed, it will become possible to perform more stable PV electric power fluctuation suppression control by a bidirectional DC/DC converter. Furthermore, using the new studied photovoltaic simulation system of GIS (Geographic Information System), PV solar energy density calculation of PV installation location can be performed. As shown in Fig. 7, it is possible to do the construction of the system of the solar energy operation distributed best on the map based on the decentralized energy distribution in the area confirmed by the new proposed 3D-GIS observing system [14].

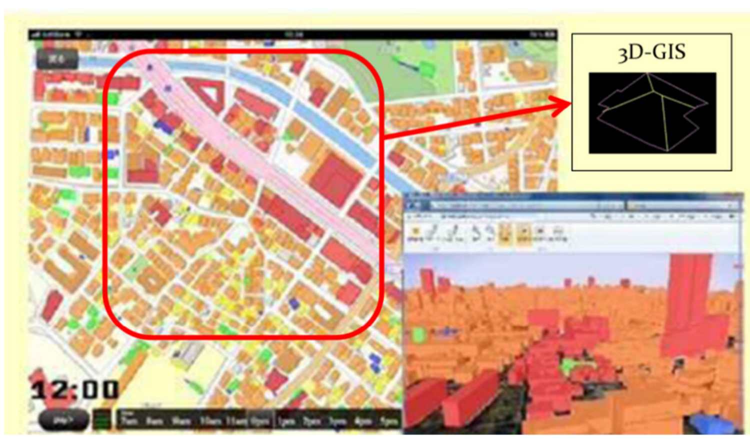


Fig. 7. PV Generator Fluctuation Suppression System Using GIS.

3. Conclusions

In this paper, the basic energy reduction approach to create green innovation especially about the LED lighting, Power system, and new energy control system has been shown. It is important to satisfying the world noise guideline of LED lighting by the best LED circuit selection. It is also more possible to construct the LED circuit without connecting the equipment for the noise reduction. On the other hand, the Charging-discharging of electric power in the system batteries required to suppress the fluctuations of the PV output has been evaluated. From In this result, it is sufficiently possible to suppress the fluctuation of PV output in each household by compensating 1.0-1.2 kW power. In other words, if the system is introduced into one million households in a certain area, it corresponds to the Load Frequency Control (LFC) capacity with 1 GW of thermal power station. Furthermore, a little PV change inhibitory control of the influence of weather change becomes possible by applying GIS. We have proposed the construction of a stable, economical, clean and safe energy supply system so as to support sustained economic and social development in line with sustained energy development.

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