DISASTER-PROOF SMART GRID USING SHIPS TO USE RENEWABLE ENERGY

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The renewable energy is eagerly expected but the electric output is too unstable to use. In this situation, the SMART system with three functions was proposed in 2004. The first is to provide the good circumference to use the renewable energy. The electricity is exchanged between the grid and demand-side with distributed generation, heat storage and electric battery. The second is to provide the visualization tool to cooperate with citizens. The advanced demand-side control promotes the energy saving and accepts the fluctuating output of renewable energy. The third is to provide the electricity from ships or EV (electric vehicle) at emergency.

Keywords: renewable energy, SMART grid, demand-side, citizens, disaster-proof

INTRODUCTION

In the conventional system, the electric power is supplied only to the demand-side from the utility grid. On the other hand, the electricity is exchanged between the grid and the demand-side with a help of ICT (Information & communication technology) in the disaster-proof SMART grid using ships. The ships and harbor are very important infrastructures for the safety of society and citizens. The name of SMART is come from SMall Advanced Regional Energy Technology. The system [1,2] proposed in 2004 has three important functions. The first is to provide the good circumference to use the renewable energy. The renewable energy is eagerly expected but the electric power output is too unstable to use. The total control of distributed generation including ships, heat storage and electric battery is important to compensate for the renewable energy. The second is to provide the visualization tool to cooperate with citizens. The advanced demand-side control promotes the energy saving and accepts the fluctuating output of renewable energy. The energy action of approximately 400 neighboring houses is recommended instead of the conventional HEM (Home energy management). The third is to provide the electricity from ships or EV (electric vehicle) in black out of the utility grid at emergency.

GOOD CIRCUMFERENCE TO USE THE RENEWABLE ENERGY

The electric demand of daytime is several times of that of night. The demand also strongly depends on the economic activity, climate and season. The continuous full-power operation of large power stations is difficult due to the changing demand. The continuous and steady operation assures the high efficiency of state-of-the-art large power station. Furthermore the portion of renewable energy has to be increased to reduce the emission of carbon dioxide (CO_2) in the energy strategy of Japan. The renewable energy is eagerly expected but the electric output is too unstable to use. In this situation, the demand-side control is requested along with the total control of distributed generation, heat storage and electric battery to accept the renewable energy.

The conventional grid systems supply the electric power one-directionally to the demand-side as shown in Fig.1. The electric power company has a duty to supply the power demand requested by the users. So they have to prepare the enough capability of electric supply to the demand-side simultaneously requested from all the users. If the balance of supply and demand is broken, the frequency of electric power begins to fluctuate and may results as a black out in worst case. So when a lot of renewable energy such as wind or solar power is introduced into the conventional grid, the fluctuation of power generation may make an unstable condition of grid. For the example, the solar power quickly reduces the electric output at the cloudy weather. The wind power also reduces the power at the weak wind conditions. If the wind speed becomes half, the electric output becomes less than 10 %.

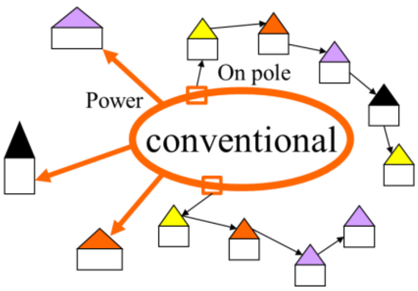

Fig.1 Conventional system

On the other hand, SMART grid is the interactive power supply system by using ICT as shown in Fig.2. The system can visualize the balance of demand and supply, and sometimes enforces or recommend users to reduce the electric demand.

The conventional grid is the **technical system** to supply the power requested by the users. On the other hand, SMART grid is the **social system** to adjust the necessary power based on the interactive communication with the users. In the ancient down town of Tokyo, the people in condominium used to lend and borrow the soy sauce or salt. The people of SMART grid also lend and borrow the electric power to use the fluctuating renewable energy and avoid the steep usage of power.

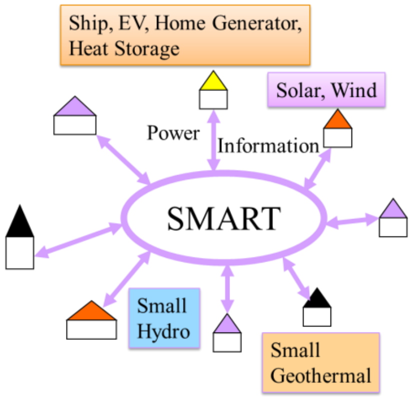

Fig.2 SMART

The small heat & power is widely adopted in the facility such as hospital or factory where a lot of heat is necessary to operate when the operational cost can be saved in spite of the expensive initial cost. In these case, the significant cost saving can be possible by the base load operation with the contract reduction of maximum electricity demand. But the unpredictable blackout takes place at the malfunction of heat & power generation system. The network of these distributed generation sites prevents these accidents with accommodation of electricity and heat between the sites. The network also contributes to reduce the fluctuation of demand on the utility. Furthermore if the network of distributed generation cooperates to cut the peak demand, the large power station of utility can operate steadily with the high efficiency.

Recently plug-in hybrid(PHB) or electric vehicle (EV) which can be charged at home has appeared. If the charging is done in the midnight, the significant cost cut can be obtained. The PHB using the conventional Ni-H battery can cut the cost by 41%. Furthermore the more advance lithium-ion battery has been developed to provide the larger capacity and compactness. This advanced battery is quickly replacing the conventional one. The spread of vehicle with the advanced battery indicate the appearance of town or community with the storage system of electric energy. The midnight electricity and renewable energy can be stored in the battery system and the efficient usage of energy can be attained. The Japanese typical EV shown in Fig.3 has a lithium-ion battery of 16 kWh. So this battery can gives 8 kW for 2 hours. When 125,000 cars exist in a community, the total electric power is 1,000 MW as same as a large nuclear power station.

Shown in Fig.4 is the home small heat & power generation with gas engine. In the electric power generation of 8 kW(efficiency of 30%) and hot water storage tank of 200 liter. Only 1hour operation of the system is needed to make the hot water of 90°C. When 125,000 houses have this distributed generation system, the total electric generation is 1,000 MW as same as a large nuclear power station. The power can be changed with changing the number of operation.

The network of distributed battery or generation can supply the huge power as same as the large nuclear station. The difference from the nuclear station is the flexible control of electric supply or generation by changing the operating number of distributed battery or generation. If the citizens cooperate to change the timing of release the electricity from the EV battery or preparing the hot water, the flexible power of 1,000 MW can be obtained. This flexible power is very important to accept and use the fluctuating renewable energy.

Fig.3 Japanese typical EV

Fig.4 Home small heat & power generation

The Japanese disaster prevention committee has pointed out that the economic loss of 112 trillion yen and the death of 13,000 peoples due to the earthquake directly above its epicenter at the capital of Tokyo. The number of death summarizes at Tokyo, Saitama and Chiba prefecture. It is predicted that the 200 peoples die due to the accident of bullet train called as Shinkansen. Furthermore 7 million peoples loss the houses. At the emergency, the distributed battery or generation can contribute to supply the electric power safely to the local community isolated from the large utility grid.

In the recent mass production system, unification of mechanical parts is often recommended to cut the production cost. An unexpected defect of the parts sometimes results as the massive and extensive recall. The diversity of energy resource is very important and necessary for the redundant and safety community.

VISUALIZATION OF ELECTRICITY DEMAND

Electricity demand is measured with sensor and transferred with Wi-Fi or 3G network as shown in Fig.5. The special software developed with Linux can provide the demand on the open WEB at every 1 to 2 minutes.

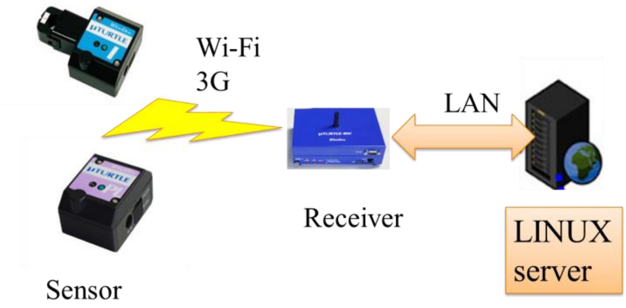

Fig.5 Measuring system of electric demand

Fig.6 Yokohama Hakkeijima Sea Paradise

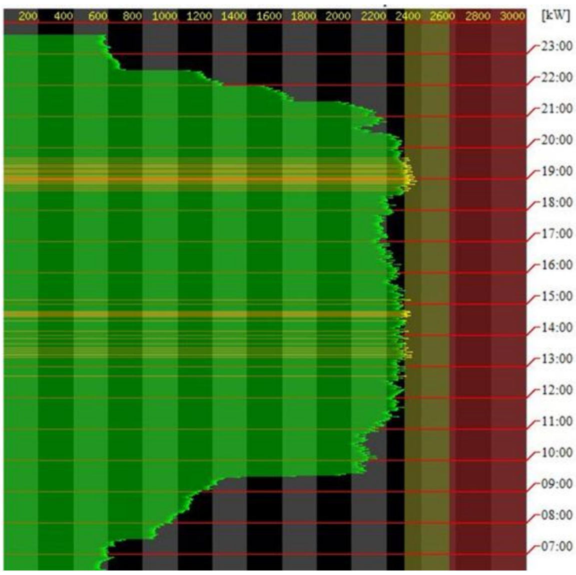

Fig.7 Display of electricity demand on web

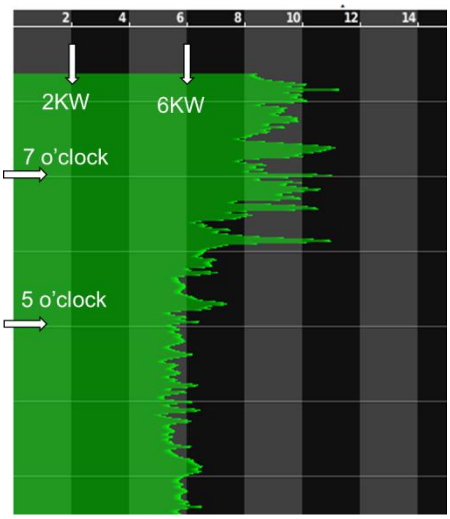

Fig.8 Electricity demand of 20 houses

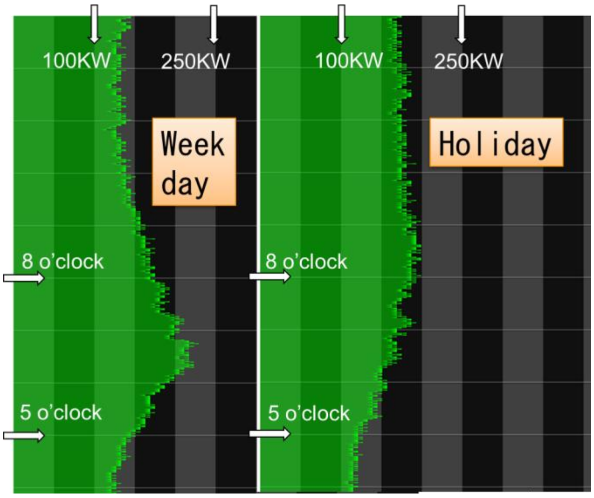

Fig.9 Electricity demand of 309 houses

Since the summer in 2012, the system for visualizing power consumption in the office building and the aquarium facility has been contributing to a 10 percent reduction in power consumption at Yokohama Hakkeijima Sea Paradise (Fig.6).

Shown in Fig.7 is the electricity demand disclosed on web at every 2 minutes. The employee and guests can easily confirm the total electricity demand of office or facility on their smart phone or PC. The display is a simple bar graph of green. The red zone is the maximum demand contracted with the utility and yellow zone is the 10% reduction. When the demand enters into the yellow or red zone, the bar changes to yellow or red to call the attention of users. The energy saving of amusement park is attained with keeping the comfortable and safety circumference for the guests.

At the residential area near the Sea Paradise, the visualization experiment is also conducted. Shown in

Fig.8 is the electricity demand of 20 houses disclosed on web at every 1 minutes. In the morning, the demand begins to increase at 6 o'clock from approximately 6 kW. Several spikes corresponding to the usage of electric appliances such as rice cooker or washlet can be recognized. It has a possibility that this recognition can be used to detect the abnormal condition or sudden illness of elderly person who lives alone in a house.

On the other hand, the electricity demand of 309 houses is shown in Fig.9. This data is also measured at every 1 minute but the spikes like 20 houses disappear. The demand at a week day has a peak between 5 and 8 o'clock. However that at a holiday does not have a peak. The demand begins to increase at 5 o'clock and stays at a constant from 8 o'clock. These electric demands on web are used in the energy saving action and accepting the unstable renewable energy.

EMERGENT SUPPLY OF ELECTRICITY FROM SHIPS OR EV

As one of the cost cutting for mooring ships, electric power supply from land is becoming popular. Shown in Fig.10 is the supply wire and equipment for the ship of coal transportation. This system also contributes to reduce the exhaust emission and harmful substances from ship diesel engine. In the Yokohama harbor, 0.2 million ton of CO_2 can be reduced. This system also secures the power supply apart from the utility in case of emergency and disasters.

Japanese utility has the sophisticated power supply grid and secures the reliable power supply to the users. However, the biggest damage by earthquakes results as the long black out. On March 11th, the northern part of the main island of Japan was hit by a massive earthquake, and the ensuing Tsunami occurred by the earthquake devastated the area killing numerous people and damaging on its infrastructure. Shown in Fig.11 is the ship taking refuge from Tsunami in Fukushima nuclear power plant. If the electric power of ship was used in the control room and plant, the severe accident could be avoided. Quick power supply is required to save the human life within maximum 2days in the black out. As the bigger damage is considered in the metropolis, the quick recovery of life and medical circumference should be prepared.

Shown in Fig.12 is the electric transforming unit from ship to land. The 3 phase 3 wires electricity of ship can be changed to 1 phase 3 wires for the land use. The unit can provide 20 kW which can charge 6 EV or 50 houses in the emergency.

The power from ships to land can be supplied directly with cables or with EV as shown in Fig.13. The quick charged EV can easily carry the electricity to the hospitals and shelters even if they are apart from the harbor. The harbor of coastal city should be recognized as the important infrastructure to contribute the safety of society and citizens. Not in the emergency, the electric supply to the mooring ships and loading equipment from the utility reduces the emission of CO_2 in the coastal area. These would be supported with the ship owners and consignors who are sensitive to the environmental conservation.

Fig.10 Electric supply wire and equipment.

Fig.11 Ship taking refuge from Tsunami in Fukushima nuclear power plant.

Fig.12 Electric transforming unit from ship to land

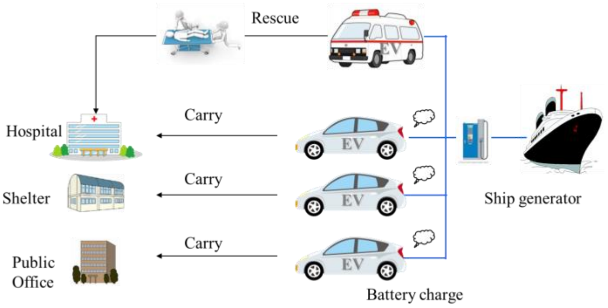

Fig.13 EV and ship power

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