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SMART SYSTEM FOR DISASTER-PROOF COMMUNITY WITH DISTRIBUTED ENERGY AND IT NETWORK

KAWANA Masataka
Tokyo University of Marine Science & Technology
Koto-ku, Tokyo 135-8533, Japan

OSAKABE Masahiro
Tokyo University of Marine Science & Technology
Koto-ku, Tokyo 135-8533, Japan

MOURI Kunihiko
Tokyo University of Marine Science & Technology
Koto-ku, Tokyo 135-8533, Japan

ABSTRACT

Variety researches and developments have been performed in order to decrease the emission of carbon dioxides as known of major cause on global warming. The SMART study group has proposed a concept of the solution for the low carbon dioxides emission and the disaster-proof community cooperating with industries, academics and municipal offices. This concept is based on the distributed energy network as known as SMART grid technology proposed in 2004. The system consists of the micro-grid system with distributed energy and IT network securing the power supply apart from the power utility in case of emergency and disasters. The proposed SMART system has major three functions. The first is to provide the ability to use the renewable energy generated in the local community. The renewable energy is most expected one but the output is too fluctuating to use usually. The second is to provide the tools to cooperate with citizens. The advanced demand-side control can contribute to save the energy. The third is to prepare for the disaster as mentioned above.

INTRODUCTION

The SMART study group[(1)] was established in Tokyo University of Marine Science & Technology at 2003 following the energy basic policy enforced at June, 2002. The policy indicates the three important principles as,

1. Security of supply
   Self-sufficiency ratio for energy of Japan is only 4%(19% if the nuclear energy is included) but those of the advance nations except Germany is more than 50%. The security of energy supply is unavoidable in Japan.
2. Accommodation to circumstance
   The concentration of carbon dioxides was approximately 280ppm before the industrial revolution at 18th century and is reaching to 400ppm recently. The energy policy considering the conservation of circumstance is important and the trade mechanism of carbon dioxides emission should be discussed. The market size of carbon dioxides is foreseen as much as 25 trillion yen.
3. Application of market economy
   The electric supply has been monopolized by the electric power company in Japan. The deregulation should be progressed step by step as,
   - By April, 2004: Deregulation of electric supply less than 500kW (deregulation ratio of 40%)
   - By May, 2005: Deregulation of electric supply less than 50kW (deregulation ratio of 63%)
   - At 2007: Start of discussion on the full deregulation. The electric power company can monopolize the power transfer using the grid but the privilege to request the power transfer by newcomer should be guaranteed.

As the result of energy policy, the electric power company tends to promote the all-electric houses and the gas supply company propagates the home generations. The former is electric supply with the large power station and the latter is with the distributed small generation[(2)]. The two parties tend to enlarge the territory based on the market economy principle but the total higher efficiency of Japan can be achieved only by the cooperation of two parties.

Shown in Table 1 is the demand-side efficiency of electric power generation of the electric power company in Japan. Japanese government determines the effectiveness of distributed small generation for energy saving by comparing with the large power station using the fossil fuel. The energy saving law denotes the average efficiency of large fossil power station is

36.9% as shown in Table 1. However, the combined cycle of 1300°C class as the turbine inlet temperature in gas turbine component is 45% and that of 1500°C class is 50%. These high efficiencies has attained with the higher temperature of combustion and the larger scale of facility.

On the other hand, the small heat & power is often used to supply both the electric power and heat as the distributed generation. In this case, the low efficiency of electric power generation is unavoidable due to the small scale of facility. Table 2 shows the example of small distributed heat & power with the lower efficiency compared to the above mentioned high efficiency of large power station.

Shown in Fig.1 is the relation between the transported heat and the electric consumption of typical heat pump (air conditioner) used in home. The assumed temperature difference between outside and inside is 13°C for heating and 8°C for cooling. In spite of the larger temperature difference between outside and inside in the heating, slightly larger heat transportation is obtained compared to the cooling at a given electric consumption. The higher capability of heat transportation in heating than that in cooling is due to the characteristic of heat pump thermodynamics. The ratio of transported heat to electric consumption is called as COP (Coefficient of performance). In the figure, the lines of COP=3 and 6 are indicated and the data for heating and cooling approximately agree with the line of COP=3. Three times heat of electric consumption can be transported with the heat pump system.

Recently COP of small heat pump less than 4 kW of transported heat becomes more than 6. The COP of the larger heat pump tends to exceed 3. This ability is much larger than the absorption type refrigerator[(2)] of which typical COP is between 0.7 and 1.2. As the absorption type is driven with heat and its COP is lower than the usual heat pump using electricity.

The new electrical heat pump[(2)] using carbon dioxide as a working fluid can provide the hot water more than 90°C and its COP is between 3 and 4.5. This heat pump system is replacing the conventional home boiler with electric heater. However the COP strongly depends on the temperature difference and the degradation should be considered especially at the outside temperature less than 0°C.

As the demand-side efficiency of advanced combined cycle is up to 50%, 30% of generated electricity can be used in lighting or motor and 20% can be used in heat pump of COP=3 as shown in Fig.2. So 60% of heat and 30% of electricity can be used in this case. On the other hand, the efficiency of small heat & power is low as 30% but the exhaust heat of 60% can be used on site. The exhaust heat can be changed to cooling by using the absorption refrigerator of COP=1. It should be mentioned that the large power station and small heat & power can provide the same heat and electricity.

However it is very difficult to use the absorption type refrigerator in home as the initial and maintenance cost is not small. So the absorption type refrigerator can be used only in the relatively large facility.

Table 1 Demand-side efficiency (based on HHV)

Average of fossil fuel power	36.9 %
Combined cycle(1300°C class)	45.0
Combined cycle(1500°C class)	50.0

Table 2 Demand-side efficiency of small heat & power (based on HHV)

300kW class gas engine	30.0 %
300kW class mirror cycle gas engine	38.0
2.5MW regenerative gas turbine	36.0

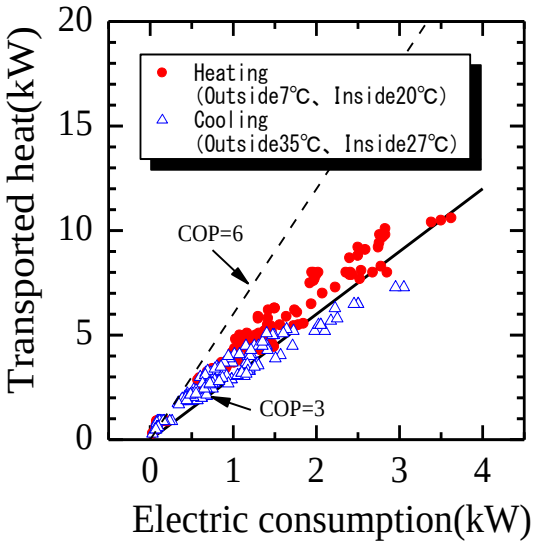

Fig.1 Performance of home heat pump at 2004

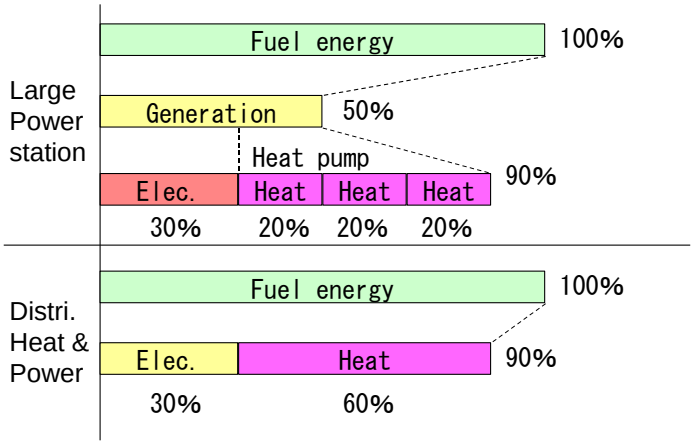

Fig.2 Equivalency of small heat & power and large power station

The equivalency of small heat & power and large power station is established only when the heat is used for bath or room heating at home. The COP of electrical heat pump has a possibility to increase furthermore but the degradation due to a frosting of heat exchanger is expected at the outside temperature less than 0°C in winter.

DIVERSITY OF ENERGY

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 contract reduction of maximum electricity demand. But the 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 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 use the fluctuating renewable energy.

As one of the cost cutting for mooring ships, electric power supply from land is becoming popular. Shown in Fig.5 is the supply wire and equipments for the ship of coal transportation. This system also contributes to reduce the exhaust emission and harmful substances from ship diesel engine. This system also secures the power supply apart from the power utility in case of emergency and disasters. Japanese power utility has the sophisticated power supply grid and secures the reliable power supply to the consumers. However, the biggest damage by earthquakes such as Kobe-Awaji resulted as the long black out of approximately 7days in the community. Quick power supply is required to save the human life within maximum 2days in the black out. As the biggest damage is expected in the metropolis, the quick recovery of the life and environmental load reduction should be prepared.

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.

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.

Fig.3 Japanese typical EV


Fig.4 Home small heat & power generation

Fig.5 Electric power supply from land to ship

Fig.6 Cruise ship “Queen Mary II”

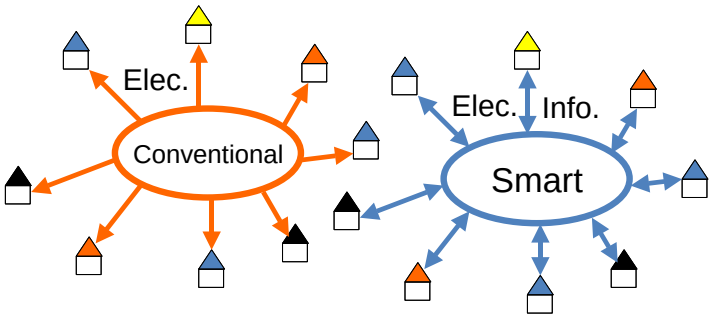

Fig.7 Difference of conventional and SMART grids

By the way, the electric generation capability of ship is tremendous. Shown in Fig.6 is the famous cruise ship “Queen Mary II”. She has 6 engines to generate the electricity of 114 MW which is enough for electric demand of 28,000 houses. Actually, the foreign cruise ship in Yokohama had contributed to rescue the refugee in the large earthquake called as Kanto great earthquake at 1923.

SMART GRID

President Barack Hussein Obama is working aggressively on the economic recovery of Unite States from 2009. The present business recession was worst after the great depression in 1929. President proposed the green innovation to stimulate the economy and promote the environmental conservation. As one of the important energy policy, SMART grid is the object of world people’s attention. The SMART grid is the advance interactive power supply system by using the information communication technology (ICT).

When talking about this advanced SMART grid system, some people says the Japanese grid is enough smart compared to the other country’s grid system. This misunderstanding prevented the budget proposal to verify the SMART grid by the SMART study group[(1)] in 2004. The SMART grid is totally different from Japanese conventional grid system.

The conventional grid systems supply the electric power one-directionally to the users as shown in Fig.7. The electric power company has a duty to supply the power demand given by the users. So the electric company has to prepare the enough capability of electric supply to correspond to the demand requested simultaneously 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 fluctuating of power generation may make an unstable condition of grid. The solar power quickly reduces the electric output at the cloudy weather. The wind power also reduces the power at the weak wind conditions.

On the other hand, SMART grid is interactive power supply system by using information communication technology (ICT). The system can visualize the balance of demand and supply, and sometimes enforces users to reduce the electric demand. The conventional grid is the technical system to supply the given 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.

The major rolls of SMART grid are followings.

1. The usage of the fluctuating renewable energy becomes easy. When the output of renewable energy is large, automatically

the electric price decreases and promotes to use or store in the battery system such as EV. The stored energy can be used or sell to the grid at the time of high electric price. When the output of renewable energy is small, automatically the electric price increases and refrains to use or sell from the battery system such as EV. Sometimes it enforces to reduce the demand of users.

2. Energy saving of individuals is promoted with the visualization of energy by SMART grid. It is important that individuals know the total energy of community and act for energy saving. The local government also can notice the effect of policy for the energy saving.
3. The quick power supply is available at the disasters such as earthquake by using the renewable energy or battery of EV. The ships also can provide the electric power to the community after emergency mooring. In the black out, it is pointed out that 83% of hospital in downtown of Tokyo becomes malfunction. The SMART grid can immediately provide the electric power to the hospitals at the black out of utility and saves the life. The inhabitance of high building cannot return to their house without elevator at the black out. Their evacuation place at the earthquake is their house in high building. So the SMART grid helps them to return to their house.

The other day, the fluctuation of frequency occurred at a condominium of high building. The fluctuation resulted as the malfunction of some electric equipment such as kitchen oven or Induction heating(IH). The cause is the simultaneous operation of heat pump system to store hot water in tank. More than 800 heat pumps simultaneously started to operate in the early morning for usage of the day and noise was put on the power supply line. The heat pump system is energy saving equipment and replacing the conventional home boiler with heater as mentioned above. Approximately 3 times heat of electric consumption can be used to make a hot water but the timing to operate cannot be controlled now.

On the other hand, small heat & power at home is widely sold to make hot water with the exhaust gas of electric generation by using gas engine or fuel cell. 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. If the citizens cooperate to change the timing to make hot water, the flexible power of 1,000 MW can be obtained. This flexible power is very important to use the fluctuating renewable energy.

The battery system of 6 trillion yen would be needed to introduce the renewable energy as much as 30% of maximum electricity demand of Japan. Instead of the huge battery system, the many small batteries in PHB or EV can be used in SMART grid. As the EV and PHB are expected to increase further in future, it is sure that the cluster of these small batteries can support the mechanism of flexible SMART grid.

It is important to control the room temperature as same as the control of operational timing of heat pump boiler. People can feel comfortable at the room temperature of only 7°C higher than outside in the cold winter season because they put on the warm wears. The decrease of 1°C reduces the electric consumption by 10% in the air conditioning heat pump. In the hot summer season, it is possible to increase the room temperature as the same reason. The SMART grid can control the room temperature in the wide area and can yield a significant saving of energy.

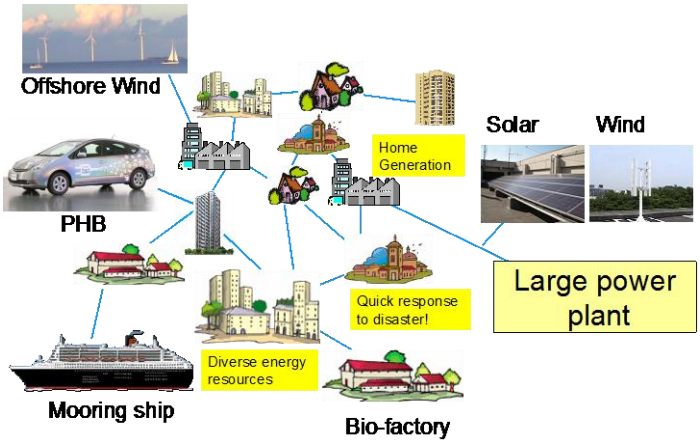

Fig.8 SMART grid accepting the various energy resources

Some people say the prompt introduction of renewable energy can be attained with environmental tax. If the SMART grid to use the energy wisely is introduced in our life, the tax will be effective. But now Smart grid is not complete and the prompt introduction of renewable energy may results as the unstable condition of conventional grid system.

ROLL OF CITIZEN

When the environmental tax was introduced in Germany, there were a lot of objection but gradually granted by citizens. The cooperation of citizen is very important always in the environmental conservation. The citizens of Stockholm, where is the capital city of Swedish, have been suffered with the heavy traffic jam. The entrance tax was introduced to the entering cars into the city center zone. The tax can be charged automatically with reading the license number at all the bridge to enter the central city zone. The tax also depended on the amount of traffic. This tax system successfully reduced 20% of traffic and 14% of the carbon dioxides emission.

The public traffic, cars for physically challenging people and environmental friendly cars such as PHB and EV were excluded from the charging of tax. It should be noted that the tax is less than 100 yen. Why people in Stockholm refrained from entering into the central city zone with the small amount of tax? A lot of people with the mind of environmental conservation are in Europe and Japan. It is considered that the main reason for the refraining is not due to the payment of tax but due to the mind for the environmental conservation. The tax could promote and push their mind to conserve the environment. An incident such

as small amount of tax is necessary to promote citizens to act for the environmental conservation.

The power of citizen will be a strong tool for energy saving with SMART grid accepting the various energy resources as shown in Fig.8. It should be mentioned again that the diversity of energy resource is very important and necessary for the redundant and safety community.

SUMMARY

The SMART study group[(1)] was established at 2003 following the energy basic policy enforced at June, 2002. The major proposals are followings.

1. As the result of energy basic policy enforced at June, 2002, the electric power company tends to promote the all-electric houses and the gas supply company propagates the home generations. The former is electric supply with the large power station and the latter is with the distributed small generation. The two parties tend to enlarge the territory based on the market economy principle but the total higher efficiency of Japan can be achieved only by the cooperation of two parties.
2. As the demand-side efficiency of advanced combined cycle is up to 50%, 30% of generated electricity can be used in lighting or motor and 20% can be used in heat pump of COP=3. So 60% of heat and 30% of electricity can be used in this case. On the other hand, the efficiency of small heat & power is low as 30% but the exhaust heat of 60% can be used on site. The exhaust heat can be changed to cooling by using the absorption refrigerator of COP=1. It should be mentioned that the large power station and small heat & power can provide the same heat and electricity.
3. When 125,000 houses have the distributed batteries or generation systems, the total electric supply is 1,000 MW as same as a large nuclear power 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 use the fluctuating renewable energy.
4. As one of the cost cutting for mooring ships, electric power supply from land is becoming popular. This system contributes to reduce the exhaust emission and harmful substances from ship diesel engine. This system also secures the power supply apart from the power utility in case of emergency and disasters.
5. The proposed SMART system has major three functions. The first is to provide the ability to use the renewable energy generated in the local community. The renewable energy is most expected one but the output is too fluctuating to use usually. The second is to provide the tools to cooperate with citizens. The advanced demand-side control can contribute to save the energy. The third is to prepare for the disaster. The quick power supply is available at the disasters such as earthquake by using the renewable energy or battery of EV. The ships also can provide the electric power to the community after emergency mooring.
6. An incident such as the small amount of tax is necessary to promote citizens to act for the environmental conservation. The power of citizen will be a strong tool for energy saving with SMART grid.

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