Remarkable CO_2 Reduction of the Fixed Point Fishing Plug-in Hybrid Boat

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Abstract

It is quantitatively shown that this fishing system using a plug-in hybrid fishing boat (PHEB) provides an outstanding CO_2 reduction performance of more than 80 % compared with the simple diesel engine operation. This research has been conducted at the fishing area around a detached fishing island, Nushima, Japan. Based on the actual fuel consumption patterns of fishing by the fishermen, the quantitative analysis of daily fuel consumption was performed. The remarkable reduction of oil consumption is due to the high efficiency of the electric motor and the idling stop function during fixed fishing operation. The population of Nushma is 500 and 162 fishing boats are in daily operation. Among them, 117 boats (72 %) are working daily as a kind of fixed point fishing. When the access velocity and the return velocity of 30 minutes totally is decided, the daily fuel consumption by fixed position fishing is determined. It is also determined based on the actual fishing data that fixed point fishing is 8 hours daily in average. Using the CO_2 reduction result of 80 % in this study for the fixed point fishing operation, it is expected that 468 kL (20 L × 117 boats × 250 days × 0.8) of the fuel and 1,220 ton-CO_2 can be reduced annually. In Japan, about such 50,000 boats are fishing. So even in Japan, the total amount of CO_2 reduction expected can reach 61,000 tons annually. This research has been conducted as part of the newly developed S2G two-way electricity transportation system (from ship to grid and from grid to ship) using the PHEB to prove the effective use of renewable energy for ship propulsion and successful reduction of CO_2 emission under the research program of "Empirical study of the independence distribution energy system technology based on DC technology in a detached island and a fishing village" financed by the Ministry of Environment of Japan subsidy 2014-2016.

Keywords

ship to grid, electric, boat, plug-in hybrid electric boat, renewable energy, CO_2 reduction

1. INTRODUCTION

Under the research project of "Empirical study of the independence distribution energy system technology based on DC technology in a detached island and a fishing village" financed by the Ministry of Environment of Japan subsidy 2014-2016, the S2G research has been conducted. This research has aimed to demonstrate the usefulness of the independent distribution energy system based on renewable energy. S2G stands for Ship to Grid. A demonstration of the performance of S2G (ship to grid) is described by Minami et al. [2010; 2015].

The system of the plug-in hybrid boat, PHEB, takes an important role to the S2G. A photograph of PHEB and the system of the PHEB are shown in Figures 1 and 2 respectively. The system of S2G is shown in Figure 3. The electric energy of the PHEB propulsion is supplied by a Li ion battery stored in the grid system. The battery is charged by the solar cell of 46 kW and a wind generator of 1 kW at the detached island, Nushima in Japan.

On the occasion of a blackout by disaster, the electricity can be supplied from the PHEB generator via the charged battery loaded in a special EV called the mobile vehicle to the communication systems and the lighting systems to maintain sustainable life in the detached island. Attention is focused to prove the effectiveness of the S2G system at Nushima Island. As one

Fig. 1 A photograph of PHEB

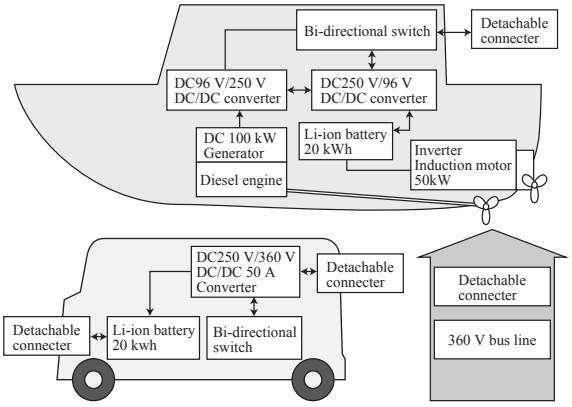

Fig. 2 The system of the S2G, ship to grid

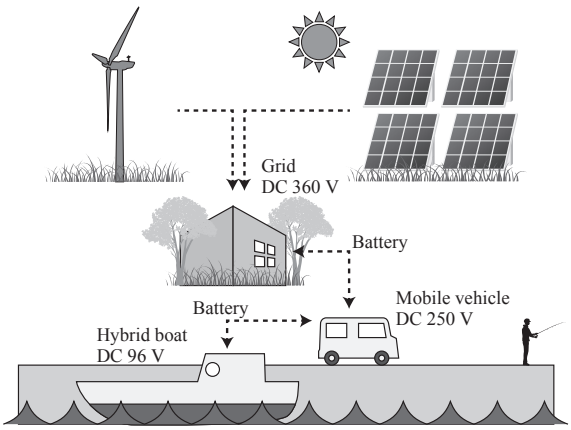

Fig. 3 The image of S2G system at the detached island, Nushima

of the purposes of this research, experimental studies on the CO_2 reduction to fixed point fishing operation by the fishermen's daily work at the island was conducted.

Under the Nushima research project, the CO_2 reduction rate of the PHEB system performance for fixed fishing operation conducted by the fishermen living at the Nushima Island was evaluated. One preliminary qualitative examination was made on CO_2 reduction performance in FY2013 campaign. In this paper, more quantitative analysis is made. The image of S2G system at the detached island, Nushima, Japan.is shown in Figure 3.

1.1 Plug-in hybrid boat, PHEB

Two PHEB (plug) systems were fabricated. One is a prototype model of the plug-in hybrid boat. It shows an effective performance of low noise, locally no polluted gas emission, and low vibration by electric mode, and reliability because of the hybrid mode with a diesel engine. It was also shown in the previous report [Minami et al., 2003; 2004; 2013a] that the fuel consumption of the newly developed PHEB as shown in Figure 1 is excellent when used for fixed point fishing operations. In the area of Nushima, fixed positon fishing operations have been made [Minami et al., 2013b]. In the project, this PHEB plug-in hybrid fishing boat was experimentally used during the campaign.

An electric propulsion system of the newly developed PHEB is installed independently from the previously installed diesel engine propulsion system. This system can be applied for different boat propulsion systems. To demonstrate the performance of PHEB, a 4 tons existing 38 ft diesel (140 kW at maximum output power) inboard propeller fishing boat is used.

The PHEB can be driven by either a diesel engine or an electric motor selected manually. The two propulsion systems can be operated independently. In this paper, more detailed and quantitative evaluation is made. This system would have a high potential to spread because of easier and lower cost for the modifications.

1.2 Performance of the S2G electric system

The purpose of the S2G research is to construct an electric energy transportation system from the 360 V grid system charged by the renewable energy of the solar electric power and the wind power and to prove the world's first system's high efficiency. One electric vehicle (20 kWh total battery stored energy) called the mobile vehicle is also used to transport the electric energy obtained by the solar cell power line (Grid) with the Li-ion battery system (30 kWh) to the boat during the normal G2S operation. The boat can also produce electric power so that it can be supplied to the grid via the electric vehicle when natural disasters happen. The capacity of the mobile vehicle is 20 kWh/ 250 V and it is sufficient to charge from the ship to the grid and vice versa. The battery in the PHEB ship is 20 kWh/96 V. While the battery capacity of the DC grid is 46 kWh with 360 V. The possible power of the DC/DC converters are 10 kW at maximum. The system and the image of the S2G are shown in Figures 2 and 3 respectively.

It has been pointed out that the system production of the PHEB can be made by modifying used boats instead of building a new one. To contribute to the total energy saving and to improve the environment, the factor of the total amount of volume is significant for the life cycle assessment. The number of used boats in Japan is about 200,000. Recently only about 2,000 new boats were sold in the total Japanese market. The modification of used boats has better cost merit than new boat production. The research to evaluate the CO_2 reduction during fishing was conducted for the effective use of PHEB system to contribute to the environ-

mental issue.

2. RESULTS OF CO_2 REDUCTION OF THE PHEB DURING DAILY NUSHIMA FISHING OPERATION

CO_2 reduction is an important issue to be solved to minimize foci-fuel resources. Many technological efforts have made to improve the reduction rate of CO_2 emission for years. Among them, it is important to point out here that the fishing industries have a high potential to modify old boats to provide effective CO_2 reduction by fixed point fishing. This fixed point fishing pattern is appropriate for the hybrid propulsion. In the water, slower velocity movement has great advantages to fuel consumption, because fuel consumption is proportional to the cube of the velocity. Due to the limited energy density of batteries compared with diesel oil, it is important to know the appropriate electrification of the boat. As described previously, a series of plug-in hybrid boats (the PHEB) were developed with the Kansai Electric Power Co., Ltd. (KEPCO) based on such a kind of thought. The PHEB fishing boat at Nushima Island can be powered by natural energy resources.

Under the Nushima project using solar cell and wind power financed by the ministry of environment during FY2012-2014, attention has been focused to evaluate the performance of CO_2 reduction rate by the use of the PHEB fishing boat. The Nushima project aimed to demonstrate energy independence by using renewable energies based on solar cells and wind power.

The main job of the people in Nushima Island is fishing. The amount of CO_2 emission exhausted from life by the total population of 500 is much smaller compared with that by 162 fishing boats registered in this island. The patterns of the fishing boats are categorized into two. One is a kind of fixed point fishing, and the other is continuously powered propulsion fishing such as bottom trawling. The way of trawling needs a lot of power continuously during fishing. It is improper to introduce electrification for such a purpose. Both patterns need a diesel engine to go and return between the port and fishing points as a realistic point of view.

The daily average diesel oil consumption by the registered fishing boat is about 50 L. The average CO_2 emission from each fixed point fishing boat per day in average is about 20 L and the total CO_2 emission by such a boat per year (250 working days) is estimated to be about 10.4 tons.

The fishermen doing fixed point fishing spend about 8 to 9 hours without moving and just maneuvering at a certain fixed point. The period to access or return to the point is about 15 minutes. Figure 4 shows a photograph of the typical fixed point fishing near the island.

Fig. 4 Typical fixed point fishing near the island

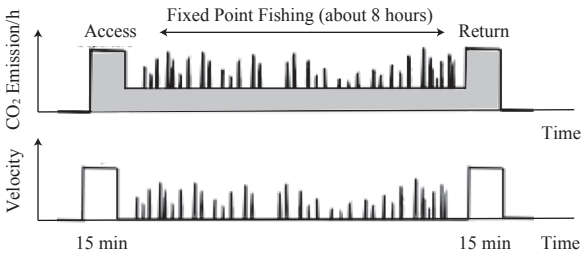

Fig. 5 A schematic drawing of a daily pattern of fixed point fishing near Nushima Island

The PHEB makes it possible to contribute to reduce CO_2 emissions for the fixed point fishing operation by the following method. The access and return to and from the point is evaluated by a diesel engine and the maneuvering at the fixed point is driven by an electric motor with engine idling stop. Figure 5 shows a schematic drawing of a daily pattern of fixed point fishing by Nushima fishermen.

Figure 6 shows an example of typical position tracing of the PHEB with respect to the water, measured by an accurate 3D flow velocity meter, during a fixed point operation. Figure 7 shows the change of position, x and y, with respect to the global position measured by GPS. The maneuvering method depends on the type of fish. Figure 8 shows a typical electric power consumption during the fixed point fishing operation conducted by PHEB.

In this comparative study of CO_2 reduction, a pattern of fixed point fishing was decided based on the actual fishermen's fishing as shown in Figure 5. The relationship between the fuel consumption by fuel flow meter and the engine revolution of PHEB was obtained as shown in Figure 9. The PHEB used is almost the same fishing boat as the real fishing boats at Nushima Island to evaluate the fuel consumption pattern. When the access velocity and the return velocity are given, daily

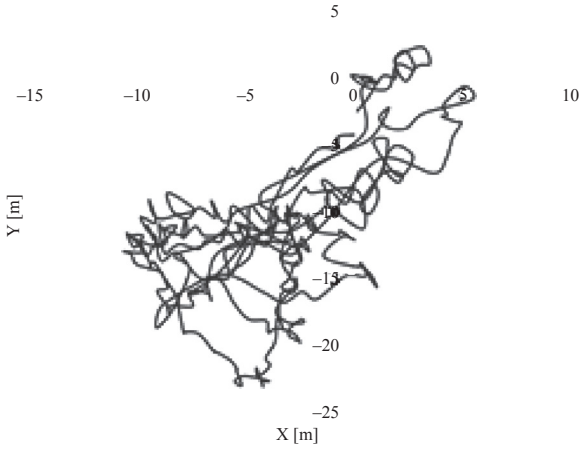

Fig. 6 An example of typical position tracing of the PHEB with respect to the water measured by an accurate 3D flow velocity meter during a simulated fixed point operation

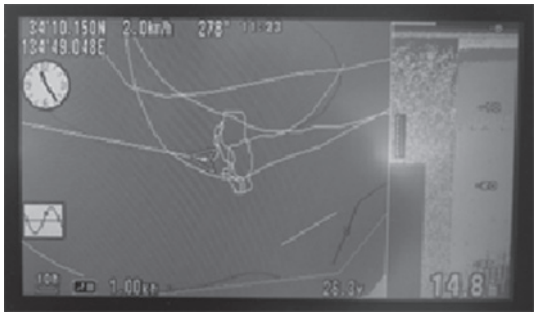

Fig. 7 The change of position, x and y, with respect to the global position measured by GPS

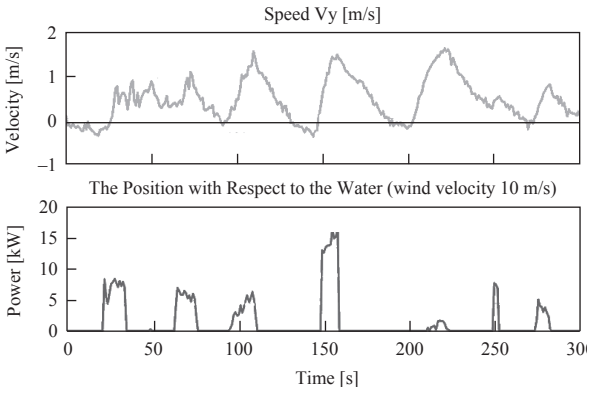

Fig. 8 Typical electric power consumption and the velocity of the fixed point fishing boat during the fixed point fishing operation conducted by the PHEB

fuel consumption by each fixed position fishing boat can be determined. It is assumed that the diesel engine is used for both plug-in hybrid-type boats and diesel engine fishing boats during access to the fishing point and return to the port. The difference is that the plug-in hybrid fishing boat, PHEB, uses the on board electric motor and performs idling stop during the fixed position fishing for 8 hours each day.

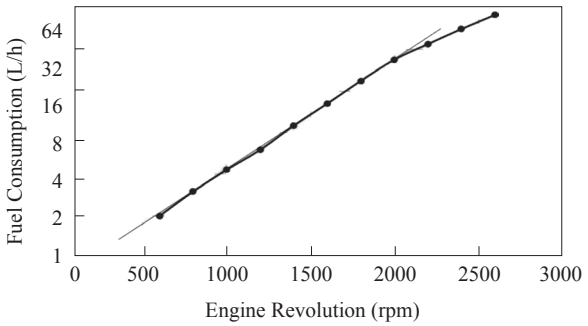

Fig. 9 The relationship between the velocity and the fuel consumption of PHEB

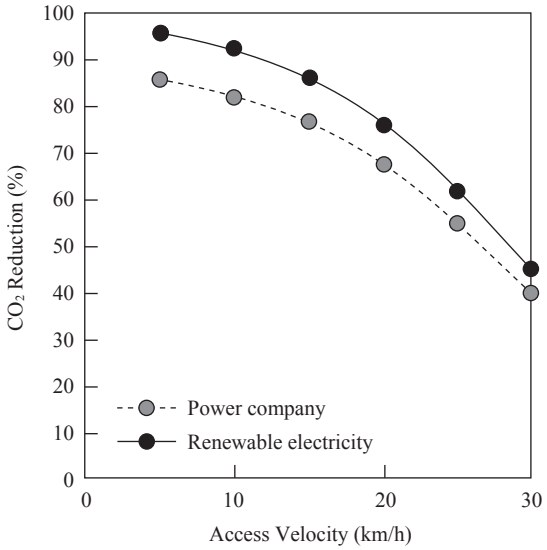

Fig. 10 The CO_2 reduction by the use of PHEB to the normal diesel engine boat for the wind velocities of 10 m/s, and for the different electricity energy sources of electric power company and the renewable energy

It is well known that the CO_2 emission from the electric motor is reduced by about 50 % to the diesel engine running during the same driving speed. The CO_2 emission from a diesel engine (assuming the efficiency of 20 %) is 1.3 kg-CO_2/kWh, while an electric motor (assuming the efficiency of 85 %) emits 0.65 kg-CO_2/kWh, when the CO_2 emission to make electricity is assumed to be 0.5 kg-CO_2/kWh. This is the reason why the CO_2 emission by the electric motor is roughly 50 % to the diesel engine operation.

From this fact, it is possible to estimate the CO_2 emission. When the renewal energy is used for electric propulsion, it is said that the CO_2 is no longer emitted during fixed point fishing of 8 hours.

Based on such an assumption, the total fuel emission as well as the CO_2 emission can be calculated. Only the parameter is the velocity for access to the fishing

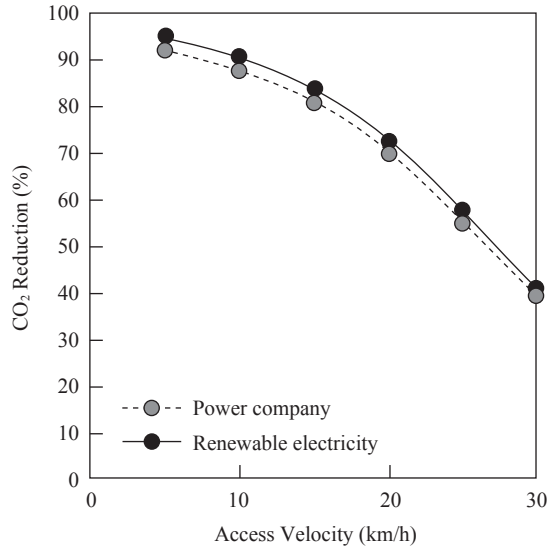

Fig. 11 The CO_2 reduction for the wind velocities of 5 m/s

point and the return. Figure 10 shows the CO_2 reduction by the use of PHEB to the normal diesel engine boat for the wind velocities of 10 m/s for two different energy sources of electricity from the power company and renewable resources. Figure 11 shows the CO_2 reduction for the wind velocities of 5 m/s. The time of the boat for access to the fishing point and to return to the port is assumed to take 30 minutes totally. In the graphs, effectiveness of the CO_2 reductions by the renewable electricity is shown.

3. DISCUSSION AND CONCLUSION

Under the Nushima project in FY2012-2014 to demonstrate an energy independent society at a detached island, a ship to grid (S2G) experiment using a 38 ft. LOA plug-in hybrid boat, PHEB was performed.

The purpose of the S2G research is to construct an electric energy transportation system from the 360 V grid system charged by the renewable energy of solar electric power and wind power into a plug-in hybrid fishing boat and to prove the world's new system's high efficiency. The renewable energy transfer to the plug-in fishing boat was successfully performed with about 90 % of transmission efficiency.

At the Nushima Island, 162 fishing boats are in daily operation. Among them, 117 boats (72 %) are working as a kind of fixed point fishing. Using the CO_2 reduction result of 80 % based on this result to the fixed point operation, it is calculated that 4,000 L of annual oil saving and 10.4 t of CO_2 reduction per one fishing boat can be obtained. Also 468 kL (20L × 117 boats × 250 days × 0.8) and the 1,220 ton-CO_2 can be reduced per year at the island totally. In Japan, about 50,000 of such boats are fishing. So even in Japan, total amount of CO_2 reduction can reach 520,000 tons even without the use of renewable energy resources. When renewable electricity is used, the CO_2 reduction in Japan can be reach 600,000 tons per year.

Based on the actual fuel consumption patterns of fishing at Nushima Island, it is shown that the ability of idling stop function by the electric motor drive during the fixed fishing operation can provide outstanding CO_2 reduction.

The usefulness of such a plug-in hybrid boat, PEHB, is also pointed out. Such a hybridization for marine application can bring more effective CO_2 reductions compared with the land car's hybridization. The electrification of a marine engine as a plug-in hybrid is recently a crucial issue because such a plug-in hybrid boat (PHEB) can obtain electric energy from the renewable energy resources such as solar power or wind energy. In addition to the efficiency of performance, PHEB brings the great improvement to the environment of noise, no toxic gas emissions as well as fuel consumption for fishermen. The modification of PHEB, plug-in hybrid boat, is easy from the currently used fishing boats or pleasure fishing boats. So it is concluded that the introduction of a PHEB type boat has a strong cost merit to reduce the total fuel consumption and the CO_2 reduction in the world.

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