CONSTRUCTION OF A PRELIMINARY AUTONOMOUS ENERGY SYSTEM USING REGENERATIVE ENERGY

Nobuharu Okamitsu[1], Ken Kai[1,2], Isamu Yamasaki[1,2], Koji Oda[2], Hideharu Tanaka[3] and Prof. Dr. Eng. Takeshi Tanaka[1]

Hiroshima Institute of Technology[1], Digicom Co.Ltd[2], CHUDENKO CORPORATION[3]

n.okamitsu@nifty.com

Abstract: *Building up a low-carbon society has become one of the world's common challenges. 'Power to Gas' efforts – to convert electric power derived from renewable energy into hydrogen – are being actively conducted, mainly in Germany [1]. Similar efforts are being made in Japan. For example, concerned Japanese cabinet members agreed on a ' Hydrogen basic strategy ' on Dec. 26 2017.[2] This strategy, with a view to 2050, shows direction and vision toward the realization of a hydrogen society and compiles an action plan to achieve that goal. It aims to scale up hydrogen consumption volume from 0.4 ten thousand t (2020) to 30 ten thousand t (2030) and deduct the unit price of hydrogen from ¥100Nm^3 (now) to ¥30Nm^3 (2030). We will also try to construct a preliminary autonomous energy system using regenerative energy. In this paper, the operation and function of such a system is described.*

Keywords: AUTONOMOUS ENERGY, REGENERATIVE ENERGY, SOLAR CELL, HYDROGEN, LITHIUM BATTERY, FUEL CELL, ELECTROLYSIS OF WATER

1. Introduction

From the viewpoints of the environment and energy security, utilizing the renewable energy is thought to be obviously important. The sun's energy can be harnessed from solar panels. Using the electrical energy of the solar panels, we produce hydrogen through water electrolysis and regenerate electricity in fuel cells. In this paper, the experimental results of managing the system and simulation results are reported.

2. System configuration

Figure 1 shows briefly system configuration. And, Table 1 is the specification of components. In the main unit, an electrolysis cell, hydrogen storage tank and fuel cell are installed and they are assumed to run their functions under the control of HEMS.

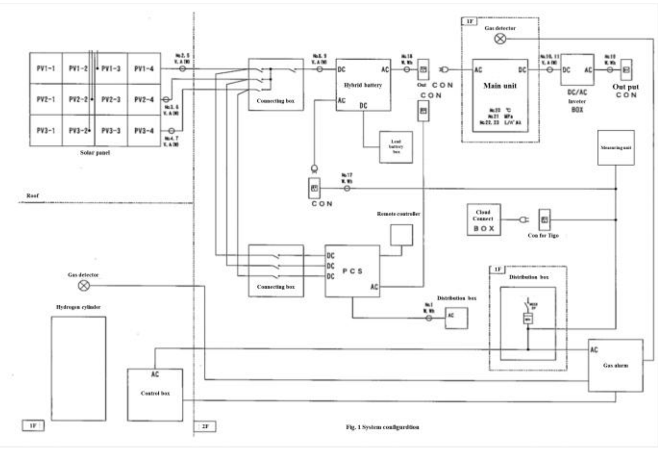

Fig. 1: System configuration

Notes: Main unit (electrolysis cell, hydrogen storage tank and fuel cell)

Table 1: *Specification of components.*

Item	Spec
PV	260w×8sheets+270w×4sheets=3.16kw/day
Battery	AC87〜265v
Hydrogen storage tank	3l
Electrolysis cell	0~500NmLPM
Fuel cell	200~300w

3. Components

2.1 PV system

Photovoltaic ('PV' for short) type solar power plant can charge the sun's energy directly into electrical energy.

Our PV panels are placed on the roof of the branch office. And we set a Tigo system [3] on every cell to manage the flexibility of solar power generation. Figure 2 shows the result of power generation by PV.

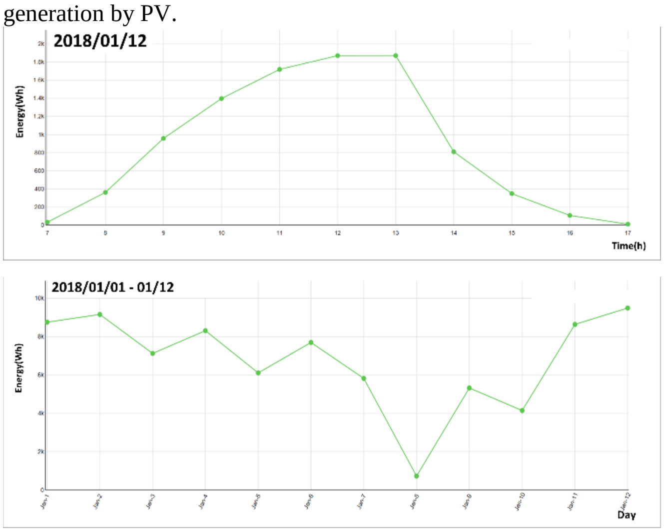

Fig. 2 *The result of power generation.*

We knot PV to the connecting box. This box can gather wirings of each solar array together one-line and send the electricity to the battery.

2.2 Battery system

The hybrid battery system is composed of lithium-ion and Pb (lead) batteries. This battery system is capable of quick charge and discharge in response to its reference signal.

2.3 Electrolysis cell

The water-electrolysis [4] means a physical phenomenon about oxidation and deoxidization of water. This reaction is only happened in a condition to apply the fixed voltage to electrodes. Its voltage is theoretically calculated at 1.229V of 25 degrees Celsius.

(1) The water is separated into hydrogen ion and hydroxide ion at the electrolyte bath. $2H_2O \rightarrow 2H^+ + 2OH^-$
(2) The electric tension presses two terminals that are soaked in electrolyte liquid. Then, at cathode, hydrogen ion combines

with electron, and hydrogen appears. It's so-called deoxidation. 2H+ + 2e- → H_2↑

(3) At anode, after electrons are deprived from hydroxide ions, oxide reaction occurs, and oxygen and water are generated. $2OH^- \rightarrow H_2O + 1/2\ O_2\uparrow + 2e^-$

Figure 3 shows the required time to fill up the storage tank with hydrogen.

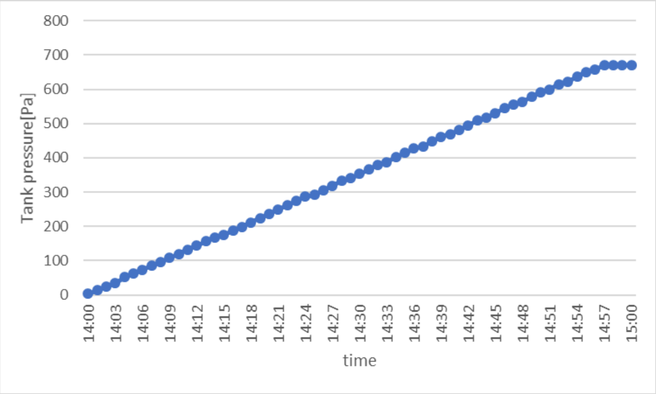

Fig. 3 *The required time to fill up the tank.*

2.4 Hydrogen storage tank [5]

The volume of hydrogen is measured in Nm^3 (Normal cubic m). $1Nm^3$ represents the amount of hydrogen with a volume of $1m^3$ under pressure of 1 atmosphere and temperature of 0 degrees Celsius.

2.5 Fuel cell

A fuel cell is a power generation plant that makes hydrogen by reacting with oxygen and produces electric energy and heat. It can directly receive electric energy from chemical energy. This reaction is the reverse of water-electrolysis.

We operated a fuel cell on Jan 12 2018 (10:00-11:00). 165l/h of hydrogen was supplied from the hydrogen tank to the fuel cell under 0.05 MPa hydrogen pressure. Then, the fuel cell generated 170 w/h of electricity.

2.6 HEMS [6]

HEMS stands for Home Energy Management System. The Government of Japan aims to establish it in all residences by 2030. This system can visualize energy usage, automatically control energy and surveil energy management. Figure 4 shows HEMS surveillance picture.

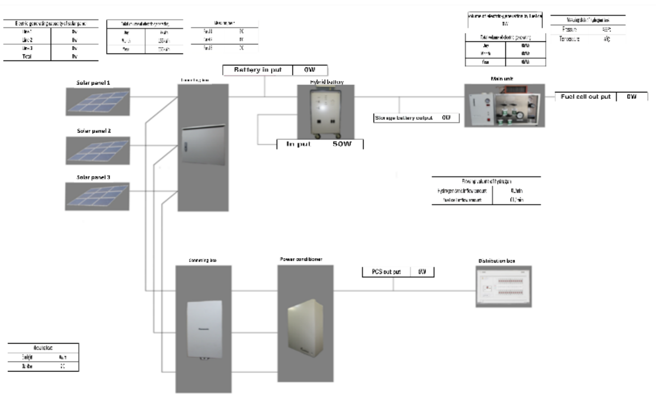

Fig. 4 *HEMS surveillance picture.*

Notes: Main unit (electrolysis cell, hydrogen storage tank and fuel cell).

2.7 Toshiba's H_2One^{tm} [7]

Toshiba continues to develop a new energy supply system that uses renewable energy to produce and store hydrogen as an energy carrier for the combined heat and power of fuel cells.

They have H_2One^{tm} in a single package that is composed of a water-electrolysis hydrogen generator, fuel cell unit, storage battery system and hot water tank. In addition, a hydrogen tank and water tank are connected to it. And they say their hydrogen EMS (Energy Management System) is a key feature of their technology. Figure 5 shows the overview of Toshiba H_2One^{tm} system.

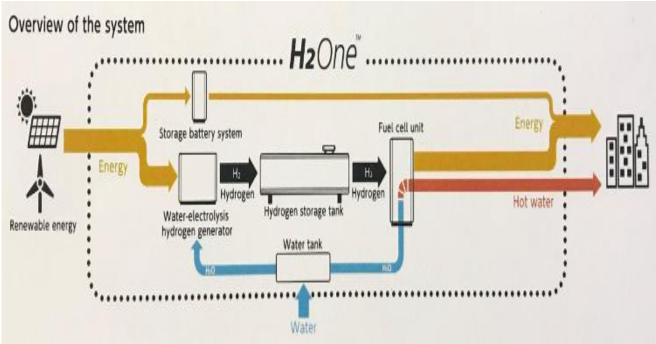

Fig. 5 *Overview of Toshiba H_2One^{tm} system.*

4. Simulation

Based on the above work, we simulated this autonomous energy system in one nursing home with its cooperation. This nursing home is located in Kure city Hiroshima Japan. It has 230 beds and consumes electricity and city gas as follows (2017).

	Electricity	City gas
Consumption volume	1,267,569kwh	149,596 m^3
Unit price	￥17.5kwh	￥78 m^3

To cover this energy consumption, we choose Fuji Electric's FC [8] (FP-100iH Spec: electricity output 100kwh, heat output 99kwh, fuel (pure hydrogen) consumption 74 m^3/h).

If this nursing home were to purchase Fuji Electric's energy by its purchase price, the total charge would be calculated as (3).

Electricity: 100kwh × ￥17.5wh = ￥1,750 (1)

Heat (Hot water): 99kwh/12.4kwh=8 m^3 × ￥78 = ￥624 (2)

(City gas 1 m^3 = 10,702kcal 860kcal = 1kwh, therefore 1 m^3 = 12.4kwh) [9]

(1) + (2) = ￥2,374 (3)

As the fuel cell consumes 74 m^3/h of hydrogen, the expected charge would be as (4).

74 m^3/h of hydrogen × ￥100 (official price) = ￥7,400 (4)

(3)<(4) cf. Hydrogen unit price correspond to (3) (3)/74 = ￥32

5. Results

Our PV generated max 1.9 kWh under sunlight peak and produced approximately 9.5 kw during sunlight hours per day (Jan. 12 2018). While hydrogen appears to be 42l/h. FC generated 170 W/h from 165l/h of pure hydrogen. HEMS can surveil and manage this system.

And, based on the results of the simulation, we find the following:

(1) Hydrogen unit price needs to be reduced from ￥100 to compare with today's electricity and town gas charges.
(2) If the supplier does not have consumers buy hot water as well as electricity, his business will not be able to cover costs.

6. Conclusion

We have constructed and operated a preliminary autonomous energy system using regenerative energy. We plan to make use of some examples of EMS or hydrogen storage technology for the future improvement of our system. Besides this, we are considering introducing the autonomous energy system to nursing homes and reducing their utility cost burden, because those costs – lighting and heating expenses – account for a large proportion of the homes' total operating costs.

Acknowledgment

The authors would like to thank Assistant Professor T. Tanioka, in Department of Electronics and Computer Engineering, Hiroshima Institute of Technology, for her kind suggestions and discussions on the English composition of the paper.

References

(1) www.meti.go.jp/press/2015/03/201603009/20160322009-c.pdf p.62
(2) www.meti.go.jp/press/2017/12/20171226002-1.pdf
(3) https://www.tigoenergy.com/ja
(4) https://panasonic.biz/appliance/FC/construction_02.html
(5) CIRED Workshop – Helsinki 14-15 June 2016 Paper 0201
(6) www.cas.go.jp/jp/seisaku/npu/policy09/pdf/20121127/shiryo04_1.pdf
(7) https://www.toshiba-newenergy.com/en/
(8) http://www.fujielectric.co.jp/products/fuelcell/spec.html
(9) Calorific value conversion table : Total energy statistics : National Resources and Energy Agency of MITE (2004 edition)