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Short communication

Evaluation of PEMFC power systems for UPS base station applications☆

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Abstract

For UPS applications such as the mobile phone base station, the selection of PEM fuel cell technology seems only feasible for the case of a heavy-duty service time requirement. The weight reduction of the whole energy system using fuel cell technology is significant, and the volume and the cost can also be superior when the service time is over 24 h. If the production cost and the module volume of fuel cell system can be further reduced, the results will be more promising.

Keywords: PEMFC; UPS applications; Base station

1. Introduction

The commercial progress of fuel cell technologies is approaching a critical point, and lots of developers are eager to look for the initial niche market. One of uses may be the application to UPS such as a mobile phone base station [1,2]. According to the present situation in Taiwan, there are over 25,000 base stations constructed by six local telecom companies. Due to typhoons, earthquakes, and floods which frequently happen in Taiwan, interruptions of electricity supply are a severe threat to uninterrupted service of mobile phones. Telecom companies usually use lead-acid batteries to extend service time during blackout periods. However, some limitations of volume, weight, and cost are considered for this UPS application. Apparently, it would not be practical to extend the UPS service time from currently 2 or 4 h to 8 h, or even 24 h. Thus, PEMFC power generators may be an interesting option for heavy-duty UPS applications.

In order to understand the effects of device cost, module weight, module volume and energy expense, comparisons and analysis of conventional lead-acid battery units and proposed PEMFC power generating systems for the UPS application in the case of base station has been illustrated and evaluated in this study.

2. System descriptions and data collection

A standard online energy system used in the mobile phone base station consists of switching mold rectifiers, control and supervisory module, ac and dc power distribution units, battery management, and low voltage disconnect switch options [3,4]. As shown in Fig. 1(a), a conventional model adopts lead-acid battery packs for supplying electricity during a blackout period. If the runtime of a base station needs to be extended, then the battery system should be enlarged. In the proposed fuel cell model as depicted in Fig. 1(b), a PEMFC

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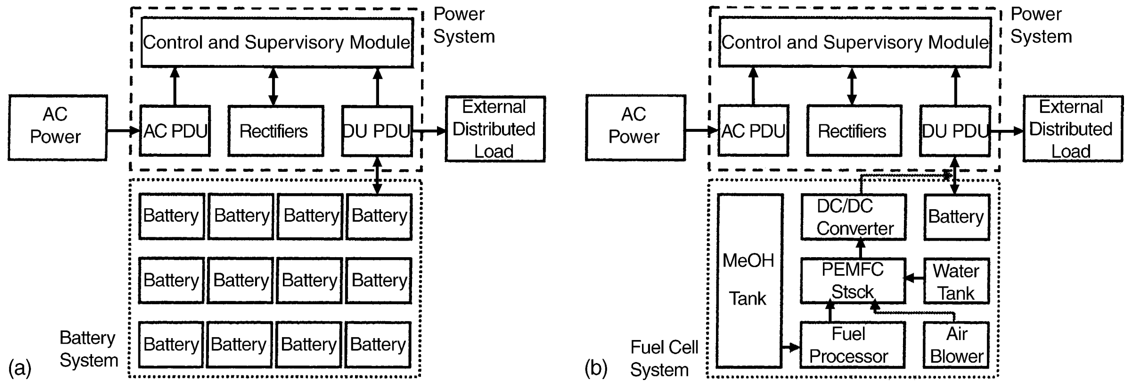

Fig. 1. Simplified schematic diagrams of the energy system used in mobile phone base stations: (a) conventional battery model; (b) fuel cell model.

Table 1
Estimation of the production cost of PEM fuel cell power generating system integrated with methanol reformer and dc/dc converter

	Production quantity (pc year^{-1})			
	1–5	50	1,000	10,000
2 kW PEMFC stack (US$)	11,642	7,463	2,985	1,493
MeOH reformer (US$)	26,866	19,403	10,448	5,970
BOP (US$)	7,761	5,970	3,582	2,388
dc/dc converter (US$)	358	269	209	149
Total cost (US$)	46,627	33,105	17,224	10,000

power generating system fueled by methanol is used instead of the battery system, and the runtime of a base station will depend on the volume of fuel tank.

A typical energy system for the base station can be assumed to have 2 kW nominal capacity and 2.5 kW peak capacity. In addition, the runtime of the energy system in the blackout period for this study will be extended from standard 2 h to 4, 8, 12, and 24 h. With the intention to analyse the difference between battery models and fuel cell models, the data corresponding to weight, volume, cost and performance of each component is collected. Most of the data about power systems and batteries were obtained from Acbel Polytech Inc., and the counterparts about fuel cell systems have been provided by Tatung Company.

Due to the fuel cell system not being a commercially viable product, the production cost absolutely depends on the customer's purchasing quantity. Estimated costs of 2 kW fuel cell systems for various production quantities are listed in Table 1. The production cost will be as high as US$ 46,627 for a small quantity, and reduce to US$ 10,000 for 10,000 units. Unlike the case of a large capacity fuel cell system, the reformer seems to be the most expensive component in a 2 kW system. Also, the costs of small and special BOP components are quite expensive, even more than those of fuel cell stacks in mass production.

3. Results and discussions

The calculated results about device cost, module weight, module volume and energy expense of lead-acid battery models for 2, 4, 8, 12, and 24 h service time are shown in Table 2,

Table 2
Calculated results of device cost, module weight, module volume and energy expense of lead-acid battery systems used in the mobile phone base station

	Service time				
	2 h	4 h	8 h	12 h	24 h
Power system (kg)	61	61	61	61	61
Battery number	4 × 1	4 × 2	4 × 4	4 × 6	4 × 12
Battery system (kg)	143	286	573	859	1,718
Rack (kg)	50	70	100	170	300
Total weight (kg)	294	417	734	1,090	2,079
Power system (US$)	4,600	4,600	4,600	4,600	4,600
Battery system (US$)	800	1,600	3,200	4,800	9,600
Rack (US$)	200	275	350	625	1,050
Total cost (US$)	5,600	6,475	8,150	10,025	15,250
Dimension (m)	0.6 × 0.6 × 0.9	0.6 × 0.6 × 1.2	0.6 × 0.6 × 1.8	0.6 × 0.6 × 3.0	0.6 × 0.6 × 5.4
Volume (m^3)	0.324	0.432	0.648	1.000	1.944
Electricity cost (US$)	0.4	0.8	1.6	2.4	4.8

Table 3
Calculated results of device cost, module weight, module volume and energy expense of PEM fuel cell systems used in the mobile phone base station

	Service time				
	2 h	4 h	8 h	12 h	24 h
Power system (kg)	61	61	61	61	61
Startup battery (kg)	111	111	111	111	111
Power rack (kg)	50	50	50	50	50
Fuel cell system (kg)	35	35	35	35	35
Fuel and fuel tank (kg)	2.5	5	10	15	30
Fuel cell system case (kg)	5	5	5	6	6
Total weight (kg)	285	287	272	278	293
Power system (US$)	4,600	4,600	4,600	4,600	4,600
Battery system (US$)	520	520	520	520	520
Power rack (US$)	200	200	200	200	200
Fuel cell system (US$)	10,000	10,000	10,000	10,000	10,000
Total cost (US$)	15,320	15,320	15,320	15,320	15,320
Dimension/power (m)	0.6 × 0.6 × 0.9	0.6 × 0.6 × 0.9	0.6 × 0.6 × 0.9	0.6 × 0.6 × 0.9	0.6 × 0.6 × 0.9
Dimension/fuel cell (m)	1.2 × 1.2 × 1.0	1.2 × 1.2 × 1.0	1.2 × 1.2 × 1.0	1.2 × 1.2 × 1.0	1.2 × 1.2 × 1.0
Volume/fuel tank (L)	3	6	12	18	36
Total volume (m^3)	1.767	1.770	1.776	1.782	1.8
Fuel cost (US$)	0.5	1.0	2.0	3.0	6.0

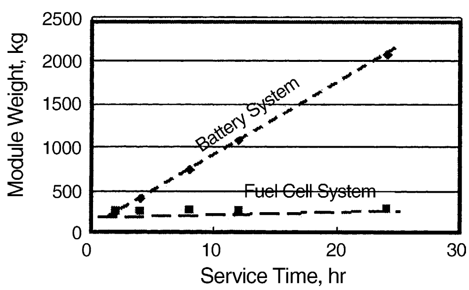

Fig. 2. The variation of module weight of energy systems vs. service time.

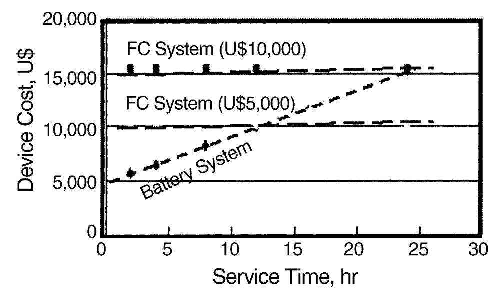

Fig. 4. The variation of device cost of energy systems vs. service time.

and the counterparts for fuel cell models are compiled in Table 3.

As shown in Table 2, the weight of a battery model mainly comes from lead-acid batteries. The total weight of whole energy system is 254 kg for 2 h of service time during blackout period, and will rapidly rise to 2079 kg for 24 h. In the case of the fuel cell model, the startup time of the reformer is approximately 30 min, thus auxiliary batteries should be installed to supply electricity before the fuel cell system can take over. As shown in Table 3, the weight of power system, startup batteries and power rack is 222 kg, and the weight of a 2 kW PEMFC power generating system is 35 kg. Both power and fuel cell systems are the same for various conditions of service time requirements, and only the weight of fuel and fuel tank will be a little different. In Fig. 2, the total weights of two energy systems are compared, and the weight

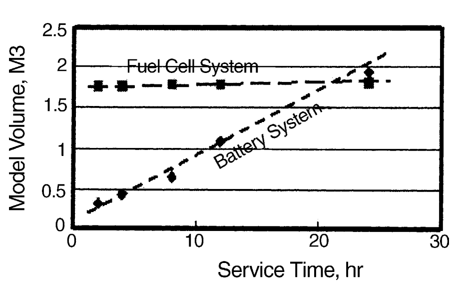

Fig. 3. The variation of module volume of energy systems vs. service time.

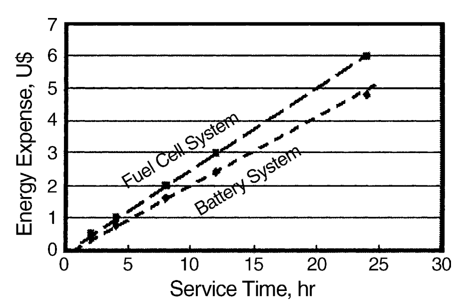

Fig. 5. The variation of energy expense of energy systems vs. service time.

of a fuel cell model is significantly lower than that of a battery model. The weights are about the same at 2 h of service time, and the difference becomes larger when the service time increases.

The total volume of a battery model depends on the quantity of batteries, and that of a fuel cell model counts on the fuel cell system. According to this study, the dimensions of a 2 kW fuel cell system including stack, reformer, inverter and case would be $1.2\,\text{m} \times 1.2\,\text{m} \times 1.0\,\text{m}$, and a GNB 100AH/12V battery used in the battery model is only $110\,\text{mm} \times 238\,\text{mm} \times 511\,\text{mm}$. From Fig. 3, the volume of fuel cell model is obviously bigger than that of battery model, but the difference of total volume will decrease as the service time becomes longer. Note that the total volumes of both systems are approaching the same value when the service time increases to 24 h.

A fuel cell model is currently more expensive than a battery model, but this may not be true for long service time requirement. As shown in Fig. 4, if the service time is 24 h, then the total device costs of both systems are almost the same, and, thereafter, the fuel cell model turns to be cheaper. The better result will be obtained if the cost of the fuel cell system drops from US$ 10,000 to 5,000. However, the energy cost of UPS operation is lower in the case of the battery model as depicted in Fig. 5. This result assumes that the electricity price in Taiwan is about US$ 0.08 $(\text{kWh})^{-1}$, and the purchasing price of methanol is close to US$ 0.18 L^{-1}.

Acknowledgements

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