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전기자동차 배터리 추적 시스템을 위한 RFID 코드체계 설계에 관한 연구

A Study on RFID Code Structure for Traceability System of Electric Vehicle Batteries

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요 약

지구 온난화, 화석연료의 고갈 등이 중요한 문제로 대두됨에 따라 전기자동차가 관심을 얻고 있다. 그러나 배터리 충전 시간, 높은 배터리 제조비용 등은 전기자동차가 널리 보급되는데 장애요인이 되고 있다. 이런 기술적 문제점을 해결하기 위한 대안으로 배터리를 교체하여 운행하는 운영 방식이 개발되었다. 배터리 교체형 시스템에서는 배터리의 공급망이 복잡하기 때문에 배터리의 신뢰성 확보 및 관리의 효율화를 위해서는 배터리 이력추적 시스템의 구축도 함께 진행되어야 한다. 본 연구에서는 전기자동차 배터리 이력추적 시스템에서 배터리 식별을 위해 사용될 RFID 코드를 설계하였다. 설계된 코드는 EPCglobal의 GRAI-96 표준을 기반으로 하였으며 배터리의 외형적 특성, 화학적 특성, 제조사, 제조일 등을 반영하였다. 설계된 코드는 RFID 코드뿐만 아니라 각 배터리의 개체식별번호로도 적용이 가능하다.

핵심어 : 전기자동차, 배터리 교환, RFID 코드, 개체 식별, 이력 추적

Abstract

As global warming and depletion of fossil fuel are considered as urgent problems, the development of electric vehicle (EV) is getting more attention by automobile industry. However, the wide adoption of EVs is not coming yet, because of many issues such as long recharging time and high cost of batteries etc. As an alternative solution to the conventional battery charging EV, the idea of battery exchanging EV is introduced. To realize the battery exchanging business model, one should solve the issues of ownership and reliability of battery. To address such issues, the concept of battery sharing should be considered together with good traceability system. In this study, we studied RFID code structure to provide better visibility and traceability for shared EV batteries. The proposed RFID code and code generation system is based on GRAI-96 of EPCglobal and included factors such as chemical, physical, and manufacturing features. The designed code can be also used as the ID of each battery.

Key words : EV, battery change, RFID code, identification, traceability

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Ⅰ. Introduction

Electric vehicle (EV) is considered as a good solution for global warming and depletion of fossil fuel. Many countries and vehicle manufacturers are trying to develop key technologies for EV and related business model. But the diffusion of EVs is not easy because of its technical limitations. One of the limitations is the long charging time of EV battery. It takes more than several hours and while the running distance is shorter than that of gasoline vehicle. The second limitation is the price of EV battery. The price accounts for almost 50 percent of the price of EV and the price of EV is two or more times as expensive as gasoline vehicle [1]. Because of these problems, the idea of battery changing EV has been getting more attention. The battery changing EV is an electric vehicle that uses exchangeable battery. When a loaded battery is discharged, the EV exchanges the discharged one with other battery which has been charged fully. The exchanging process is operated by facilities specially designed to handle big and heavy electric vehicle batteries. In battery changing business model, drivers do not have to pay for expensive battery and wait for long time to recharge his or her battery.

Also in this business model, the EV battery can be owned by government or company who can lend it to transportation companies or individual drivers. Because batteries are not owned by individual, it is important to introduce the traceability system for batteries in order to keep the history of EV batteries and to manage the EV batteries. To operate the traceability system, identification technology is required for tracking each EV battery.

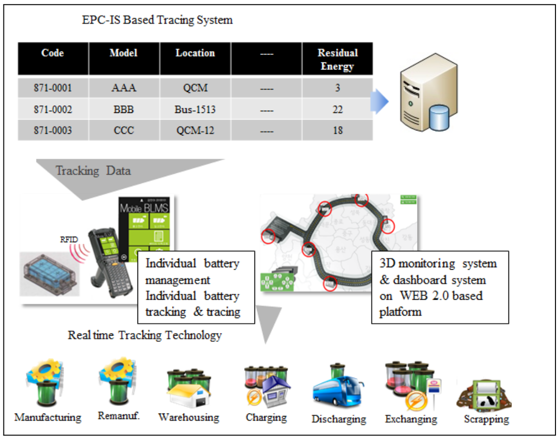
Betterplace has been operating the battery exchanging system for taxi in Japan and Netherlands and they have shown the system is profitable [2]. Korea government has been supporting a research project to apply similar idea to a public transportation system.

The purpose of this paper is to introduce the design of RFID code structure for EV batteries of electric bus which will be used in public transportation domain in the future.

Ⅱ. Previous Research

1. Battery exchange EV system for public transportation

Korea government developed ‘green car load map’ which targeted the diffusion of 1 million EV by 2020 and they have been supporting a research project called “The Korea Electric Vehicle-Transportation Safety Convergence System Research” to apply the idea to a public transportation system. In the project, battery changing electric buses and related infrastructures will also be developed to operate the battery changing bus system. The infrastructures include Quick Change Machine (QCM) that is a facility designed for changing batteries, large-scale charging center that can charge many batteries at the same time, factory that manufactures or remanufactures batteries, warehouse that stores and distributes batteries, facility that craps broken or disused batteries and battery management information systems etc. The electric bus runs on its route using changeable battery. When the battery becomes discharged, the bus exchanges its discharged battery with a charged battery in a QCM which is located at some bus stops and garages. The QCM charges batteries by itself or is supplied with charged batteries from the large-scale charging center. Because the exchange time of a battery is very short, such process time do not affect to the public bus transportation system.



〈Fig. 1〉 Battery traceability system for exchangeable EV battery of public transportation system

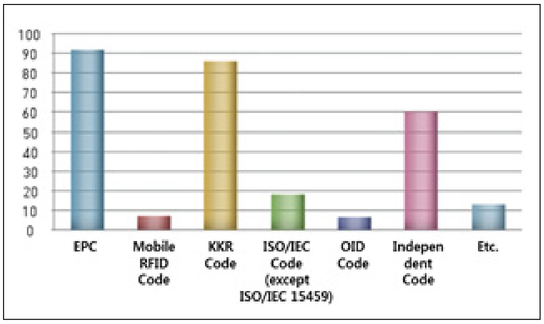
In the system, the supply chain of batteries is complex: the location of battery is changed at all time and an organization who needs to manage batteries also changes dynamically. Such frequent changes make it hard to manage the batteries information without the traceability system. A traceability system will help to acquire real-time information; to manage the historical information about batteries, and to ensure the reliability of batteries efficiently. Such information includes manufacturing data (e.g. manufacturing time, manufacturer and standard requirements) and operation data (e.g. location, the residual quantity of energy, managing company, the total count of charging and the status of defect). In our traceability system, battery ID was used as a key to access the battery data. Whenever batteries data are changed, such changes are stored and monitored by the real-time based traceability system (Fig. 1).

2. RFID code standards

In our research, we considered RFID technology as a potential identification technology for the batteries of electric bus because one can easily identify many batteries at the same time wirelessly. The technology can be applied to almost all stages of the supply chain.

RFID code structure is an important ingredient of an RFID system. The code structure has a big influence on design, quality and cost of an RFID system. And it is very hard to change an RFID code structure which was settled and is being used already [3]. RFID code structures differ by standards and are limited depending on RFID code standard that we select to use. A type of tag, reader, information system and service could be changed by RFID code standards.

There are two ways of designing RFID code structure. One is following international RFID standards to the RFID code. The other is not following standards and designing independent code structure. It is possible not to follow the standards when the target system is small and don't have possibilities to communicate with external systems. Because the use of different code standards can be a big obstacle to communicate with other system, it is desirable to follow international RFID code standards.



〈Fig. 2〉 RFID code standards used in South Korea (N=265, Simultaneously answered N=282), Source: http://www.kisa.or.kr

There are various RFID code standards. Korea Internet & Security Agency operated a survey research about a utilization of RFID/USN technology in Korea on 2010. The research questioned 265 companies which have used RFID technology about their selection of RFID code standard [4]. Fig. 2 shows the result of the question. The x-axis shows RFID code standards considered in the examination and y-axis presents the number of companies which use an RFID code standard of x-axis. The most widely used RFID code standard is EPC standard followed by KKR code in the question. EPC standard has been developed by EPCglobal which is a subsidiary of GS1. EPC structure is based on bar code number structure of GS1 and has nine kinds of type. EPC structure has ‘Header’ which distinguishes the type and each type has different service [5]. EPC standard is not official international standard but the standard is used most largely in logistics and international trade industries.

KKR code is based on ISO/IEC 15459 standard. The ISO/IEC 15459 standard consists of Issuing Agency Code (IAC) and unique identifier. ISO assigned ‘KKR’ to South Korea as IAC for public administration. The ‘KKR code is used largely in public administration and governmental supply area. KKR code consists of IAC (‘KKR’) and unique identifier. The unique identifier consists of KKR agency code and detailed unique identifier. The KKR agency is an organization which uses KKR code directly [6, 7].

3. Researches about RFID code standard

Many researches have been studied to make efficient RFID code structure and to adopt a proper RFID code standard. Kim et al. [8] studied RFID code standard, RFID tag and NPI (National Product Identifier) of Korea and developed an advanced RFID code structure of national product assets for Public Procurement Service of Korea. Paek et al. [9] analyzed an identifier of livestock and suggested RFID code structure for traceability system of livestock product. Kim [10] studied traceability system and tag issuing process for the trace of medical herbs. They designed an RFID code structure of the medical herbs. Lee [11] designed traceability system for drugs and made RFID code structure for drugs using EPC SGTIN-96 (Serialized Global Trade Item Number-96). Kim et al. [12] compared EPC standard and ISO standard using AHP (Analytic Hierarchy Process) model and suggested EPC standard for applying in munitions of Korean military. Go et al. [13] studied an RFID code interworking based system to increase compatibility of utilization among various types of RFID codes.

Ⅲ. Designing RFID Code Structure

1. Selecting RFID code standard for EV batteries

To design RFID code structure, RFID code standard should be chosen first. As EPC and KKR are used largely in South Korea, we considered both two standards.

Table 1 shows differences of the two standards [14]. The ISO/IEC 15459 standard has decentralized designing rule. Companies that use ISO/IEC 15459 standard can design code relatively flexibly. The other side EPC standards has centralized designing rule. Companies that use EPC standard should follow EPC designing rule very strictly. But because EPC standard shares designing rule and EPC Information System (EPCIS), the EPC standard has strong advantage in compatibility and expansion between EPC codes.

〈Table 1〉 Features of ISO/IEC 15459 and EPC

Division	ISO/IEC 15459	EPC
Rule of design	- Distributed - Different structure (each code)	- Centralized - Same structure (each code)
Compatibility	- Difficult	- Easy
Diffusion	- Many organizations uses (GS1 and NATO etc.) - Public Procurement Service uses in Korea	- Wal-Mart and DoD use it. - Used mainly in logistics industry.
Cost	- Only issuing agent pays NII	- All users pay to EPCglobal

Table 2 shows the compatibility of KKR and EPC for public transportation system. It is possible to design code structure of the batteries with the both standards. KKR is favorable in cost because the company that uses the standard does not have to pay. EPC is favorable when the supply chain of the batteries expands to other counties or when the battery changing technology is exported to foreign counties. In our research EPC have been selected because the advantage of EPC standard looks more valuable.

〈Table 2〉 Compatibility of KKR and EPC for exchangeable EV battery

Division	KKR Code	EPC
Domain	- Public transportation can be regarded as public administration - Possible	- Supply chain of EV batteries - Possible
Compatibility	- There is no existing RFID code for EV batteries. - Possible	- There is no existing RFID code for EV batteries. - Possible
Expansion	- Official international standards - Possible	- Easy for expanding to foreign country - Favorable
Cost	- There is no fee to pay. - Favorable	- have to pay EPCglobal. - Possible

2. Study on the identifier of batteries

To find out the elements of battery information for designing code structure, we inspected identifiers of batteries. But it was difficult to find out much information about the identifier of batteries because most manufacturers including EV battery manufacturers treat the identifier as confidential information and do not open it. Li-ion polymer battery which is used for mobile phone and lead storage battery which is used for starting vehicles were selected for this research because Li-ion polymer batteries are used for the electric bus in this project and lead storage batteries are used mainly in vehicle industry. Li-ion batteries are used mostly for small electronic devices like cell phone and mp3 player.

A battery management code of L company consists of internal management code, supplier code and manufacturing date code. The company has no code to distinguish each battery, instead they manages information of batteries by codes of manufacturing date. A battery management code of M company consists of part number, assembly product number, manufacturing date and internal management code which contains information on the factory, location of the factory, manufacturing date etc. The company has a code to identify each battery.

Retail transactions of lead storage batteries are not managed by computer system in Korea. So the batteries do not have codes for automated identification and identification of each battery. But in Korea, the batteries have manufacturing date code which is mandatory. A structure of the manufacturing date code is different from each other according to each manufacturer. But most manufacturing date codes have information on the date and the factory.

We found that the most batteries that we inspected have information of manufacturer or manufacturing plant and manufacturing date. A battery has a feature of degradation. As time goes, the quality and life span of battery decreases. In such case manufacturing date can be a useful information for the management purpose. When some batteries have a defect or danger, we can deal with the problem promptly if we consider manufacturer or factory information.

3. Factors to consider

To design RFID code structure for EV batteries, six factors were considered (Table 3).

The primary function of the code structure is to accommodate all batteries produced for long period. In this project, the EV battery pack consists of many modules and the module consists of many cells: the real object to track is battery pack. The code structure accommodates ID of battery packs. Although the target of this project is the buses operated in Seoul public transportation, the number of intra-city bus operated in whole South Korea was also considered in designing code structure to consider the expansion of electric bus system in the future. The number of the buses was 32457 in November 2010 and it was assumed that the all bus might be changed to electric bus which uses an exchangeable EV battery. Considering the expected number of buses (about 40,000), inventory (double of the number of buses) and life span (1.8 years) of EV batteries and period of 20 years, we expected the total production of EV batteries could be 1,500,000 EA at most.

EPC standard have been selected for the RFID code and we used Global Returnable Asset Identifier-96 (GRAI-96) of EPC for EV batteries. GRAI-96 is a 96 bit structure and developed for moving asset. We regarded the EV batteries as moving asset because the batteries circulate continuously throughout supply chains which consist of battery recharging stations, battery exchanging machines and electric buses.

〈Table 3〉 Factors to consider for designing RFID code

Factors	Description
The Number of Batteries	- The code structure should accommodate all batteries produced for twenty years.
Standard of RFID code	- There are many kinds of RFID code standards. - The structure of code is restricted largely by the standard of RFID code.
Length of RFID code	- The longer RFID code is designed, the larger tag memory is needed. - Long codes decrease the rate of reads.
Organization	- Factors of battery information are used to build the code structure. - Adequate factors make a code structure systemic and it is good for allocating and managing the codes.
Factors for code structure	- RFID code is just a key for accessing to information of a battery, not information of a battery. - Many factors in code structure can affect badly efficiency and security of the system.
Memory of tag	- The code structure should be designed based on the tag memory which is sold in the market. - RFID tags which have large memory are costly.

There is a trade-off among organizing code structure, increasing efficiency in reading codes and security of RFID system. Considering various factors we designed code structure which was well organized and did not decrease the efficiency and the security. Chemical type, physical type, option of remanufacturing, date of manufacturing, manufacturer were selected as factors to constitute the code structure.

4. Designing RFID code structure

In this section, we introduce the design of RFID Code Structure for EV batteries based on EPC GRAI-96 standard. Table 4 shows basic structure of GRAI-96 and details of GRAI-96 are presented in

Table 5, Table 6 and Table 7.

Table 5 shows header, filter and partition of EPC GRAI-96. Header shows that the code is GRAI-96. Filter is used to help reader to read tags and but not included in identifier. Partition determines length of GS1 company prefix and asset type. The three values are fixed.

Table 6 shows GS1 company prefix and asset type. GS1 company prefix is a decimal code given from EPCglobal. Company that has the code can manage and design a subordinate area of the structure. Generally the length of the code is 9. Asset type is a type of asset to be managed. The asset type was designed to discriminate chemical feature such as Li-ion polymer and physical feature such as size, capacity and shape. To operate battery changing system properly, the battery type should be standardized properly. Currently the number of lead storage battery type does not exceed 100 in South Korea [15]. So it is considered that 10 kinds of chemical standard and 100 kinds of physical standard are enough to accommodate types of EV battery.

〈Table 4〉 Basic structure of GRAI-96

Logical Segment	Bit Count
EPC Header	8
Filter	3
Partition	3
GS1 Company Prefix	20 ~ 40
Asset Type	24 ~ 3
Serial	38

〈Table 5〉 Part of header, filter and partition value of designed RFID code

Division	Header	Filter	Partition
Length (bit)	8	3	3
Length (decimal)	-	-	-
No. of ID	-	-	-
Example (bit)	0011 0011	000	011

〈Table 6〉 Part of company prefix and asset type of designed RFID code

Division	GS1 Company Prefix	Asset Type	
		Chemical standard	Physical standard
Length (bit)	30	14	
Length (decimal)	9 (fixed)	3 (fixed)	
		1	2
No. of ID	-	10 (0 - 9)	100 (0 - 99)
Example (decimal)	880123456	2	01

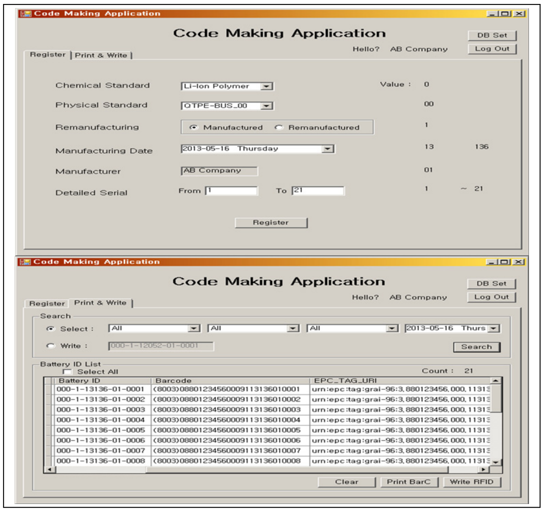
〈Table 7〉 Part of serial number of designed RFID code

Division	Serial				
	Remanufacturing	Year of manuf.	Date of manuf.	Manufacturer	Detailed serial
Length (bit)	38				
Length (decimal)	1	2	3	2	4
No. of ID	2 (1 - 2)	74 (0 - 73)	1000 (0-999)	100 (0 - 99)	10000 (0-9999)
Example (decimal)	1	13	127	07	0123

Table 7 shows serial part of GRAI-96. It was designed to discriminate an option of remanufacturing, manufacturing date and manufacturer. Using value 1 and 2, we know whether the battery is remanufactured or not. Value 0 can not be used because GRAI-96 can not have leading 0. The manufacturing year can be from 2000 to 2074 because the maximum number of the serial part is 274877906943 (2^{38} - 1). Considering the limitation of the size of EPC GRAI-96, we used 3 digits number (1 ~ 366) to represent manufacturing date. A intercalary day was also considered. Manufacturer is a company which made the battery. Considering other battery business, we assumed that the Li battery will be stabilized by big players and manufacturing operation will be highly standardized. In that respect we assumed the number of manufacturer will not be big. The detailed serial can have up to 9999. It means that the code structure can accommodate and discriminate 9999 batteries which have the same battery type and manufacturing date and are made by the same company in same manufacturing way. It is considered that the RFID code structure can accommodate 1,500,000 EA of batteries which is more than the number of batteries to be manufactured or remanufactured by one manufacturer for 20 consecutive years. The detailed serial code is assigned to battery produced and RFID tag will be attached to the battery by manufacturer. Manufacturer can design the detailed serial area at its option. For example, manufacturer can make the thousand digit of detailed serial to show factory in which the battery was made.

Ⅳ. RFID Code Generation System

We developed a software application for RFID code generation for batteries and storing the code to database. The pilot application was developed with C#, MySQL and mobile RFID reader of LS Industrial Systems (Model: IU9060). Fig. 3 shows UIs of the application. After manufacturing EV batteries, manufacturers resister the batteries with detail information. Then the RFID Code generation system generates the pure ID and the EPC Tag URI (Uniform Resource Identifier) of batteries registered. An EPC Tag URI is used for encoding the designed ID to RFID tag. The pure ID is used for identifying batteries in the other information systems not in RFID system. Manufacturer can search pure ID and EPC Tag URI generated by the application and write the EPC Tag URI on RFID tags. The EPC Tag URI can be transformed into GS1 bar code and printed in the bar code type. The pure ID can also be printed and attached to the surface of battery or RFID tag in order to be identified by naked eyes.



〈Fig. 3〉 RFID Code Generation System UI

Ⅴ. Conclusion

In this paper, we have designed RFID code structure for EV batteries which will be potentially used in the public transportation bus system in Seoul, Korea. The code structure has been designed considering compatibility, expandability and variety of application on a long-term basis. A pilot application for RFID code generation has also been developed.

When the battery exchanging bus system is widely adopted, the identification of battery will become an important issue and RFID code could be used as the identifier for managing, supplying, storing, maintaining and tracing batteries until the battery is discarded. The code may also accommodate the EV batteries of other means of public transportation like taxi in the future. It is expected that the RFID code structure in this study could be important component in developing the EV battery traceability system.

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