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스마트 그리드를 위한 홈 에너지 절감 시스템의 IEC 국제표준화 및 구현

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International Standardization and Implementation of Home Energy Saving System for Smart Grid

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요 약

가정 및 빌딩에서의 에너지 소비 절감 및 효율 향상을 위한 에너지 절감 시스템(ESS)의 새로운 구조와 기능 요구사항을 정의하는 신규 국제표준 제안서를 2009년에 IEC TC 100에 제안하고 최종 IEC PT 62654라는 신규 프로젝트로 채택이 되었다. 최근 표준 발간을 위한 최종 투표에서 만장일치로 통과함에 따라 2012년 8월 IEC TS 62654 규격이 발간되었다. 표준의 검증을 위해 ESS 서버, ESS 클라이언트, 휴대용 ESS 터미널로 구성되는 ESS 시스템의 프로토타입을 표준화 과정과 병행하여 구현하였으며, 또한 ESS 서버와 클라이언트간 통신을 위한 EPCM 프로토콜을 구현하였다. EPCM 프로토콜은 ESS 네트워크의 자동 구성, 전력 소비 모니터링, 원격 전원 제어 및 지능적인 에너지 절감 서비스를 위한 부가 기능들을 지원한다.

Key Words : Energy Saving System, ESS, IEC TS 62654, EPCM, 에너지 절감 시스템

ABSTRACT

For the reduction of electric energy consumption and its efficient use at homes or buildings, a new work item proposal for new architecture and functional requirements of Energy Saving System (ESS) was proposed to IEC TC 100 and accepted as a new project, IEC PT 62654 in 2009. Recently, the final ballot for publication passed without negative votes and IEC TS 62654 was finally published in August 2012. For the verification of this standard, Prototype of ESS system composed of an ESS server, ESS clients, and portable ESS terminal were especially implemented in parallel with the standardization. Electric Power Control and Management (EPCM) protocol for the communication between ESS server and clients was also implemented, which supports self-configuration of ESS network, power consumption monitoring, remote power control, and additional functions for intelligent energy saving services.

Ⅰ. Introduction

Due to the global warming and climate change issues caused by reckless use of energy, the efforts to develop new technologies for efficient energy generation and consumption are in progress. To enable low carbon and green growth especially in this green IT generation, Information and Communication Technologies (ICT) are being widely used all over the industrial fields. The

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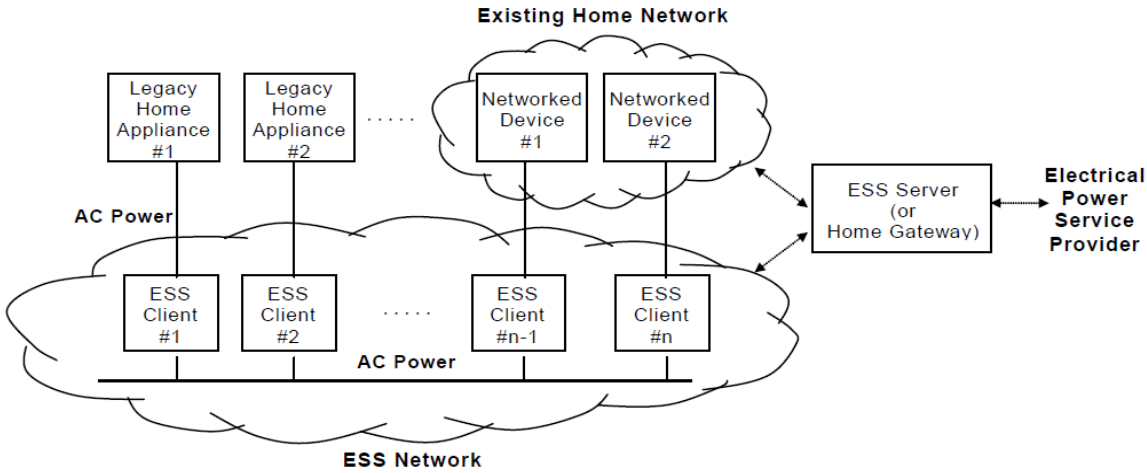


Fig. 1. Overview of ESS

Smart Grid technologies that enable the eco-friendly intelligent power grid for efficient harvesting, distribution, and consumption of electric energy, are evolving with technology development and global competition for international standards. At present, the global demand of electric energy and the emission of greenhouse gases are assumed to be increased up to 82% and 59% until 2030, respectively [1]. However, by deploying the Smart Grid, we can get energy saving effects through the reduction of the electric energy loss caused during transmission and distribution, integration of renewable energies, feedback of energy consumption information, and implementation of demand response. We can also reduce the emission of 20.3 tons of CO2 that amount approximately 124 billion dollars [2]. In this paper, we implemented ESS that can interoperate with Smart Grid and is applicable in residential area and office buildings. ESS basically provides users with information on electric energy consumed by each home appliance so that the users can voluntarily reduce the energy consumption. In addition, ESS provides various methods to control power consumption of home appliances from the remote site as well as intelligent energy saving functions. As for the international standardization, a new proposal for this ESS was proposed to IEC TC 100 by Korea Electronics Technology Institute (KETI) in 2009 and recently published as IEC TS 62654.

Ⅱ. IEC TS 62654: Energy Saving System (ESS)

2.1. Overview of ESS

The ESS network basically consists of one ESS server and one or more ESS clients as shown in Fig. 1[3]. For user's convenience, various types of portable ESS terminals can be provided.

The ESS server is connected with ESS clients through no-new-wires such as ZigBee, Wi-Fi, PLC, etc. The ESS server can be implemented either as a home gateway (or home server) type by adding the ESS server functions in it or as a standalone server type. In the first case, the ESS server can support both the existing home network and new ESS network within the Home Area Network (HAN) environment. In the second case, the server can support the ESS network only within the HAN environment. However, the ESS server provides the connection to Smart Grid or Advanced Metering Infrastructure (AMI) in both cases.

An ESS client basically supplies or blocks AC power to the connected home appliances. It measures energy consumption of each home appliance and delivers the energy consumption information to the ESS server.

A portable ESS terminal communicates with

the ESS server so as to send control commands or to display power consumption information. It can be implemented as one of the following types: remote controller type, embedded system type and smart phone application type.

Table 1. Designed functional requirements of ESS server

Connectivity (in HAN)	- Wire/wireless interfaces to ESS clients - Wireless interfaces to portable ESS terminals - Wire/wireless interfaces to the home network (optional)
Connectivity (in WAN)	- Connection to the Internet (connection to the outdoor portable ESS terminals) - Connection to Smart Grid (optional) - Connection to AMI through Smart Meter (optional)
Functions	- Support of EPCM protocol - Real-time electric energy consumption monitoring for individual appliance - Power control for each appliance group - Home ID setting - Remote power control - User interface functions - Security functions to protect private information - Standby mode learning and automatic standby power cutoff functions for appliances (optional) - Automatic power control for individual appliance by registering user events (optional) - Monthly electricity bill estimation (optional)

Each of those is connected to an ESS server through a wireless communication method such as IrDA, RF, Wi-Fi, ZigBee, Bluetooth, etc. The users can query the power consumption status through the portable ESS terminal in real time from a local or remote site, and control the power of home appliances connected to ESS clients.

As for the interfaces and protocols required for the connection between HAN and Smart Grid, no specific standard has been published yet so far, which is still controversial issue among technical committees or sub-committees under international standardization bodies. Especially, IEC SMB SG3 studies standards and standardization roadmap for Smart Grid.

2.2. Structure and functions of ESS server

The ESS server can connect ESS clients and portable terminals through the ESS network. Additionally, the ESS server plays a gateway role to connect between the inner part and the outer part as shown in Fig. 1. The functional requirements of ESS server are listed in Table 1. The ESS server can be implemented with five different types: Hand-held terminal such as smart phone, display device (wall-pad or TV) with the ESS server function, home gateway or home server with the ESS server function, PC with the ESS server function, and always-on home appliance (e.g. refrigerator) with the ESS server function.

2.3. Structure and functions of ESS client

Unlike a smart meter that measures only total power consumption in the premises and sends it to a server managed by a electrical power service provider through AMI network, an ESS client can also measure the power consumption status of each appliance to deliver it to the ESS server. Moreover, it basically supplies or blocks AC power to home appliances. In order to measure the power consumption and communicate with the ESS server, DC power components including power metering module, processing unit, low-power communication module (LPCM), and AC power switch, are required. For this purpose, a small-size of AC-DC converter is especially designed. The processing unit controls the power metering module to measure the power consumption and to deliver the measured data to the ESS server through LPCM. It also controls the AC power switch according to the power control commands from the ESS server. LPCM communicates with the ESS server. In this study, the IEEE802.15.4 based Ubiquitous Sensor Network (USN) module was used as an LPCM. A power metering module calculates the current, voltage, and energy consumed by home

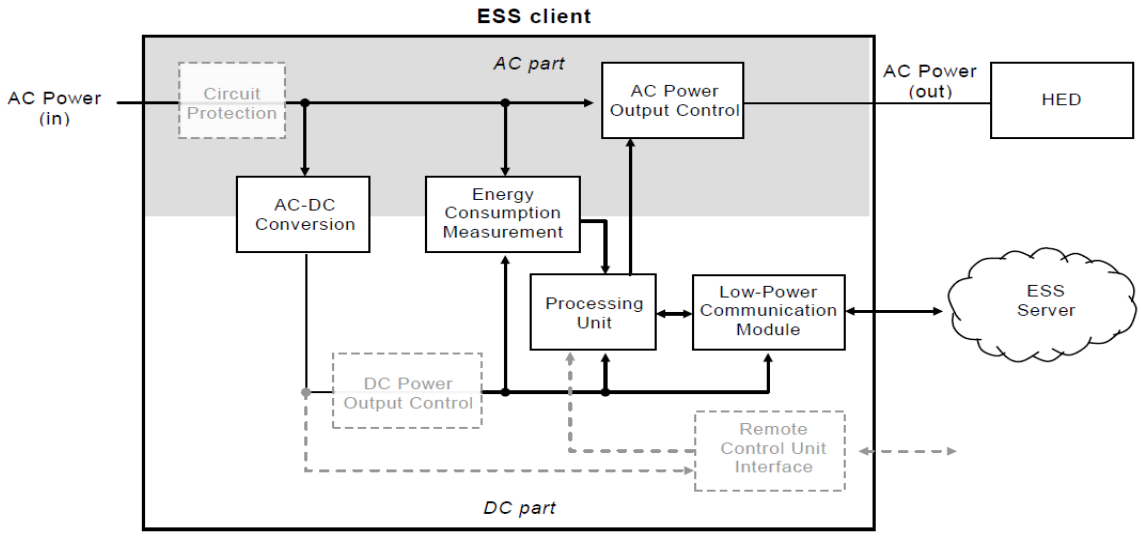


Fig. 2. ESS client

appliances. Then the processing unit periodically reads the calculated results from the power metering module. The power metering module uses the resistive divider circuitry and shunt resistor to measure the consumed voltage and current. LPF is used to internally remove high frequency and the digital filter is used for phase compensation between current and voltage. It also adjusts the measured values for DC offset, AC offset, power offset, and gain. In this study, the Cirrus Logic CS5460A chip was used as the power metering module. The functional requirements of ESS client are listed in Table 2.

Table 2. Functional requirements of ESS client

Connectivity	- Wire/wireless interfaces to ESS server
Functions	- Support of EPCM protocol - Real-time electric energy consumption measurement for individual appliance - Home ID setting - AC output control for appliances - User interface functions - Support of active, standby, and sleep modes - DC output control for low power operation (optional) - Standby mode learning and automatic standby power cutoff functions for appliances (optional)

Ⅲ. Implementation of ESS

3.1. Prototypes of ESS server

In this paper, the ESS server has been implemented with three different types as shown in Table 3. The functions of the ESS server GUI are listed in Table 4.

3.2. Prototypes of ESS client

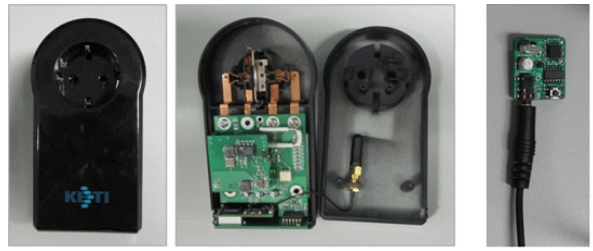
Prototype of the ESS client is shown in Fig. 3. For the low-power design of ESS client, the switch on the A-B point in Fig. 2 has been implemented with an apparatus in the AC inlet part and the home appliance has been plugged in the ESS client so that the AC power is supplied to the home appliance and the internal AC-DC conversion module to operate the ESS client. If the home appliance is not connected with the ESS client, the ESS client consumes no power (0 W). In order for a user to set the operation mode of an ESS client, a DIP switch has been designed. If it is set to “0” (/ESS_MODE = ‘0’), the function specified in Table 2 is performed. If it is set to “1” (/ESS_MODE = ‘1’), the ESS clients acts like a normal electric outlet. No metering and communication functions are enabled. As shown in Fig. 3 (b), the IR receiver that is separately located outside of the ESS client can be connected with the ESS client. The IR receiver can learn the signals of the remote control of the home appliance connected with the ESS client. While the AC power output

Table 3. Prototypes of ESS server

Types of ESS Server	Descriptions	Prototype
Hand-held device type	hand-held H/W platform with embedded Linux	
Display device type	ESS server functions added in a commercialized wall-pad system	
PC type	ESS server application for Windows and Linux PC	

Table 4. Functions of ESS server GUI

Functions of ESS server GUI	Desctiption
Home ID setting	The ESS server and clients with identical home ID can communicate with each other.
Device name setting	It is used to set the name of the connected device. It has four elements: location, device type, user name, and detailed description for specifying each device uniquely.
Power control	Four power control functions provided are as follows: 1) Real-time power control 2) Event-driven power control 3) Standby power cutoff by the standby mode learning function 4) Control for each device group (e.g. by location, device type, or user name)
EPCM command transfer	Transfer of monitoring and control commands that have been defined in the EPCM protocol
Real-time monitoring	ESS server can display the measurement values delivered from the ESS clients.
Real-time graph display	ESS server can display graphs generated from the measurement values from ESS clients.
Debugging	- EPCM protocol packet analysis - Read(write) from(to) the power metering module



(a) (b)

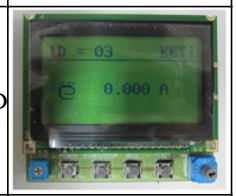
Fig. 3. Prototypes of ESS client ((a) ESS client, (b) IR receiver)

is off by a power-off command from the ESS server, when the signal learned by the remote control is received, the ESS client switches on the AC power output to the home appliance so that the home appliance can operate. This function is the most effective and intuitive method to supply power again to the inactive home appliance whose standby power has been automatically cut off.

3.3. Portable ESS terminal

The portable ESS terminal supports the IP communication with the ESS server. Using a portable ESS terminal, a user can connect with the ESS server to monitor the power consumption status for a specific home appliance and control the power. The designed portable ESS terminals have two different types as shown in Table 5.

Table 5. Prototypes of portable ESS terminal

Types of portable ESS terminal	Descriptions	Prototype
Hand-held device type (only for indoor usage)	hand-held H/W platform with LCD module and CPU	
Smart Phone type	ESS terminal application for Android smart phone (Samsung's Galaxy Tab)	

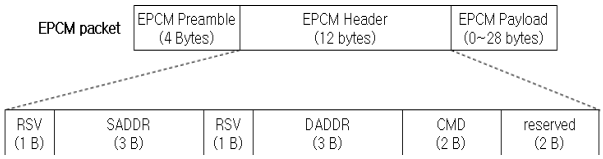


Fig. 4. EPCM packet format

Table 6. EPCM commands

Functions	EPCM commands	Description
Monitoring	MNTR_START_REQ	Monitoring start request
	MNTR_START_RES	Reply to MNTR_START_REQ
	MNTR_START_IND	Measurement value transfer
	MNTR_STOP_REQ	Monitoring stop request
	MNTR_STOP_RES	Reply to MNTR_STOP_REQ
	MNTR_PAUSE_REQ	Monitoring pause request
	MNTR_PAUSE_RES	Reply to MNTR_PAUSE_REQ
	MNTR_RESTART_REQ	Reply request in the monitoring pause status
	MNTR_RESTART_RES	Reply to MNTR_RESTART_REQ
LPCM mode control	LPCM_CTRL_IND	LPCM mode automatic conversion report
	LPCM_CTRL_REQ	LPCM mode conversion request
	LPCM_CTRL_RES	Reply to the LPCM mode conversion request
Power control for home appliance	DEVPWR_CTRL_REQ	Device power control request
	DEVPWR_CTRL_RES	Reply to the device power control request
Automatic report	NTFY_DEV_CON	Device power connection status report
	NTFY_STATUS	Device operation mode report
Smart meter registration and management	ESSID_REG_REQ	ESS ID registration request by ESS client
	ESSID_REG_RES	Reply to ESSID_REG_REQ
	ESSID_REREG_REQ	Re-registration request to all ESS clients or a specific ESS client
	ESS_ALIVECHK_REQ	Request to check whether a ESS client is operating properly
	ESS_ALIVECHK_RES	Reply to PPN_ALIVECHK_REQ
Power metering module access	PMM_REG_RD_REQ	Internal register read request by the ESS server
	PMM_REG_WR_REQ	Internal register write request by the ESS server
	PMM_SEND_CMD_REQ	Command transfer request by the ESS server

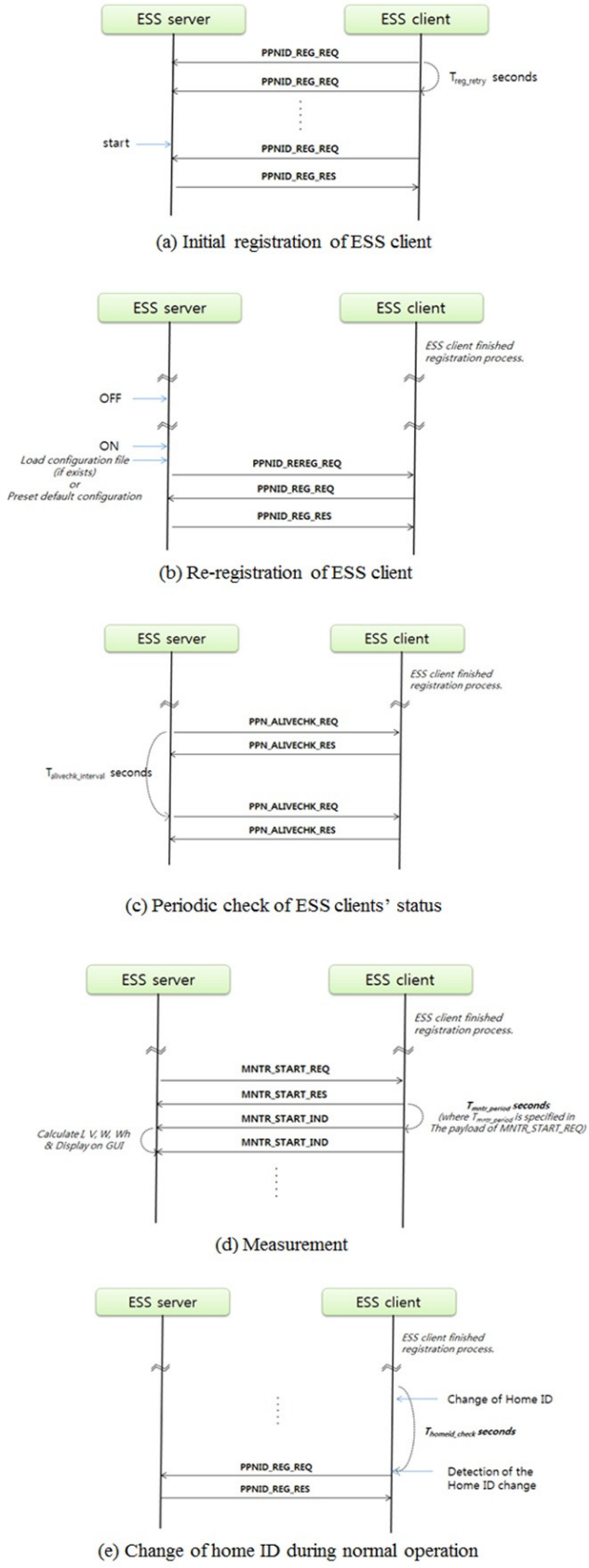


Fig. 5. ESS network management scenario

Ⅳ. EPCM protocol

4.1. EPCM packet format

The EPCM protocol is defined for the ESS network maintenance, management and control of the ESS server and clients. The EPCM packet structure is shown in Fig. 4. Especially, EPCM address format was defined to identify ESS clients. It is 3-byte long and contains 2 bytes of home ID and 1 byte of client ID. EPCM command is 2-byte long and defined for the functions of monitoring, LPCM mode control, power control of home appliance, automatic report, ESS client registration and management, and power metering module access as shown in Table. 6.

4.2. Functions of EPCM

Fig. 5 describes the registration process of the ESS client. Fig. 5 (a) is the initial registration process of an ESS client. At this time, when an ESS server does not reply to the request, the registration request message is sent again after T_{reg_retry} seconds. Fig. 5 (b) shows a case that the ESS server is turned on again for some reasons after finishing the initial registration of ESS clients. In this case, the ESS server loads the stored configuration file for GUI and sends the re-registration request messages to running ESS clients based on the configuration. Accordingly, the ESS clients perform the same initial registration process again for the ESS server to maintain consistency in the database for the ESS network management. This message can also be used for initializing an ESS client. Fig. 5 (c) shows a command used to keep the state consistency between the ESS server and clients. The ALIVE_CHECK command is used to keep the consistency on operational and power control status of ESS clients that are managed by the ESS server. This command is also used to check whether an ESS client is running or not. Fig. 5 (e) shows the home ID re-registration request process upon user's change of home ID. When the home ID of the ESS client is changed, the ESS client must communicate with an ESS server with a new home ID instead of the previous ESS server. For this purpose, the ESS client checks any change in home ID every T_{homeid_check} seconds.

Ⅴ. Conclusion

In this paper, IEC TS 62654 specifying the new architecture and functional requirements of ESS is introduced and the corresponding prototypes of ESS components including ESS server, ESS clients, and portable ESS terminals, as well as the EPCM protocol were implemented in accordance with IEC TS 62654 newly published under IEC TC 100 TA 12 in August 2012. Originally, the first presentation on the basic concept of NWIP was made in 2008, which was the first trial in IEC to standardize energy efficiency-related topics and its Working Draft was chosen as the first TC 100's input document for IEC SMB SG3, a Smart Grid strategic group. Practically, the IEC TS 62654 is applicable and extensible to In-home display, home energy gateway, home energy management system, smart meter, and in-home application of Smart Grid and potentially expected to be a basis for future international standards relevant to Smart Grid technologies.

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