Development of Smart Grid Monitoring System with Anti-Islanding Function for Electric Vehicle Charging

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Abstract

In this paper, we present a smart grid monitoring system connected with electric vehicle charging system using anti-islanding method. Electric vehicles can be charged through remote control of smart grid monitoring system and the charging process may be more stable and more efficient by virtue of wireless communication between the Local Area Module and End Modules. It is illustrated by some experiments that electric vehicle charging process continued without any serious fault even though the islanding phenomena occurred in the grid if the presented monitoring system was applied to the smart grid system.

Keywords: *Electric Vehicle, Smart Grid, Anti-Islanding, Electric Vehicle charging*

1. Introduction

The smart grid technology is expected to significantly improve energy efficiency by dynamic power supply. One of its applications is the Vehicle-to-Grid (V2G) that utilizes an Electric Vehicle's (EV) battery as a household storage battery [1]. Smart grid is new generation system and management system where modernized power technology and Information Communication Technology (ICT) are combined and converged. Smart grid technology is recognized as a core technology to realize the EV charging system, because it can maximize the energy efficiency for exchanging the information of power generation and consumption in real-time compared to the conventional one-way grid.

One of the core concepts in the smart grid is dynamic power supply. In particular, if this concept is connected to EV charging technology, it is able to improve the EV power supply efficiency through a distributed smart grid infrastructure. Moreover, EV charging can be processed both reliably and efficiently if the islanding phenomena can be prohibited during charging process. Thus, the monitoring system for observing the power generation and consumption in smart grid became necessary to prevent the islanding phenomena.

A Remote Monitoring System (RMS) is particularly useful to monitor power generation and consumption and hence, this kind of monitoring system should become an essential part of a smart grid. The configuration of conventional monitoring system consists of a hardwired industrial communication network, however, this type of monitoring system is not efficient for widely distributed small scale power sources easily shown in recent years [2].

In this paper, we propose a smart grid monitoring system connected with EVs with charging state where the anti-islanding method is implemented in the monitoring system. EV with a battery and a motor drive system was configured in HILS (Hardware-In-the-Loop-Simulation) and a micro-grid is also implemented in SILS (Software-In-the-Loop-Simulation) for real-time experiments. The validity and the effectiveness of the presented monitoring system is shown by using implemented HILSs for EVs, EVSEs, and a micro-grid.

2. The Configuration of the Smart Grid with an RMS

The structure of the smart grid with the presented RMS is as shown in Figure 1. It consists of several different components such as End Monitor Modules (EM), Local Area Monitor Modules (LAM), Wide Area Monitor Modules (WAM), and client devices. These modules use different communication technologies hierarchically, in order to ensure the reliability of the system.

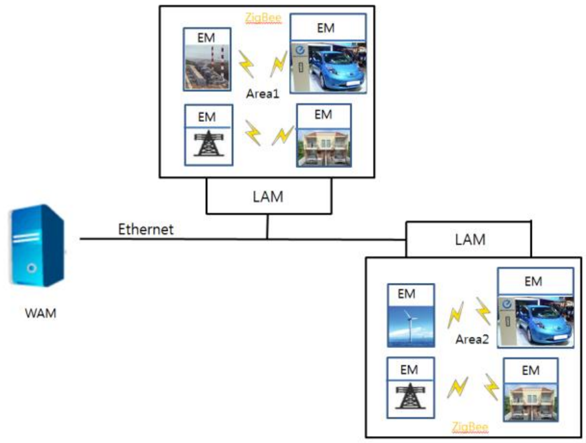

Figure 1. The block diagram of the Smart Grid with an RMS

The EM can be a renewable energy source or an EV which is charging battery or delivers electric energy to the grid. Every EM has is a kind of a wireless sensor node; EMs can be classified into three types. First, The End Power Monitor Modules (EPM) is located at each small scale renewable power generator, and monitors the generated power, the current, the voltage, the history, and the instantaneous status of the generator. Customers can check the EPM remotely on the PC. Second, the End Load Monitor Module (ELM) is placed at customer locations such as a home, an office, or a factory and it monitors the power consumption at every load site. Third, the End Grid Monitor Module (EGM) is located at the power distribution network where it is equipped with current and voltage sensors, and monitors the total power supply and consumption of the utility, the power failures, and the power quality. It calculates the harmonics of the current and voltage using FFT and detects power failures when abnormal harmonics are found.

The EPM and ELM can shut down connected devices by a command from the LAM. The EM module used in this study consisted of a main controller, sensors and a communication module. Because the EM control each end device and measure a great deal of information at the same time, the EM module should be designed to take advantage of a high-performance microprocessor. A ZigBee module is also designed and implemented for the communication between the EM and the LAM. Each EM sends the measured information to the LAM and all of the data from EMs are collected by the LAM; the LAM generates an appropriate command based on the information data. If an excessive power is generated from a distributed power source, the LAM sends commands to the EPM to reduce the corresponding power generation. On the contrary, the LAM sends also commands to the ELM to reduce the power consumption. The information monitored by each EM module is collected by the LAM in each local area, which guarantees communication reliability while maintaining the security. The LAM module has a gateway which converts the ZigBee protocol to Ethernet and the EM module will send an emergency signal to LAM as soon as any problem occurs in the generator or load,. Once the LAM module detects the emergency signal, it disconnects power path from or to the corresponding node and then, the LAM module reports this phenomena to the WAM module via Ethernet. The WAM monitors entire network in real time and customers can check the state of each node using the internet.

3. The Structure of Experimental System

To test EV charging process in real-time, HILSs for EV and EVSE are configured as shown in Figure 2 where the EVSE is connected to smart grid in which the anti-islanding method was implemented. The charging process for EVs will not be degraded seriously even when islanding occurs in the grid since the anti-islanding function detects the power failure and changes the power flow. The structure of the developed HILS is shown in Figure 2.

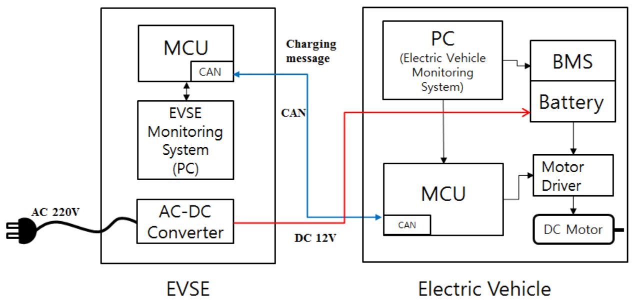

Figure 2. The Structure of Experimental System

The EVSE uses ZigBee modules for wireless network with smart grid, Main Core MCU (Micro Controller Unit) for charging management, AC-DC Converter for changing AC power to DC power and monitoring system for monitoring of EV charging status. EVSE delivers power information to EV using CAN protocol and the power information can be monitored via wireless network during charging [3].

An EV consists of Main Core MCU for the control of EV, BMS (Battery Management System) for battery information management and control, Battery, DC motor and DC motor driver for driving the EV, monitoring system for check the state of charge.

4. Anti-Islanding Application for the Electric Vehicle Charging System

A key duty of this wireless RMS is to prevent the islanding of the distributed small scale power generators. The occurrence of islanding may complicate the orderly reconnection of the electric utility network and pose a hazard to utility personnel [4], and also can impose a burden on small scale power generators. If a generator inverter has the capability of over voltage protection (OVP), under voltage protection (UVP), over frequency protection (OFP), and under frequency protection (UFP), it is said to have a basic islanding detection capability [5].

Using this basic islanding detection capability, the passive method detects islanding by observing the variations in voltage, frequency and phase when a power failure in the utility network has occurred. The active method uses the Frequency Bias, the Sandia Frequency Shift, the Frequency Jump, the Harmonic Amplitude Jump, the Power Line Carrier Communications, and the other methods. These methods detect islanding by converting the output signal of the generator to an arbitrary signal and observing the variations in the load voltage and frequency.

Existing islanding detection methods have some problems. First, due to the conversion of the generator output signal to an arbitrary signal, the power quality is reduced. Second, existing anti-islanding methods have a NDZ (Non-Detect Zero) problem [6]. Therefore, in this paper, to secure the above problems, EV charging through linking with smart grid having Anti-islanding method is proceeding smoothly and reliably seems to come true. The RMS based Anti-Islanding method of EV charging concept is shown in Figure 3.

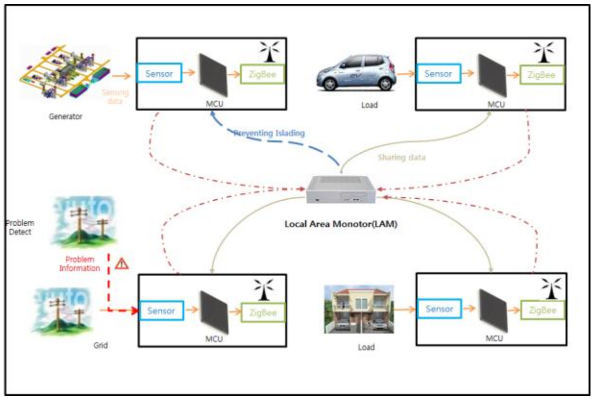

Figure 3. The RMS based anti-islanding method

5. Implementation

The drivers of EV select the power source and start charging. When charging starts, the set of sensor node data is transmitted from sensor node to the coordinator of smart grid through the ZigBee communication. If the transmission of the data is successful, the sensor nodes go back to their normal state. The received data are displayed on the PC through serial port software programmed JAVA; it can also be shown as a waveform. We can analyze the status of the distributed generator systems based on these waveforms and data. In addition, The EV charge using the power of the smart grid should proceed. Smart grid was use the normal household AC power for EV charge. EV charging status information can be seen of Using EV monitoring system. Monitoring system is shown in Figure 4.

The LAM Monitor Program　　　The Electric Vehicle Monitor Program

Figure 4. The LAM monitor program and EV monitor program

6. The Experiment Results

Experimental setup is consists of four sensor nodes and LAM. One of EM is EVSE. EV and EVSE charging connection has been progress. EVSE by connecting one of the LAM was charge in progress. We can check the charge process of during charging of EV from monitoring system. Sensor node using the smart grid monitoring system has solved the problem. The LAM get guarantees a short cut-off time to prevent islanding in less than 1 second. The result of experiment is shown in Figure 5. Figure 5 shows the detecting time of islanding and the status of EV charging voltage. If islanding occurred, EV charging voltage is a little drop down while replaced EM.

(a) (b)

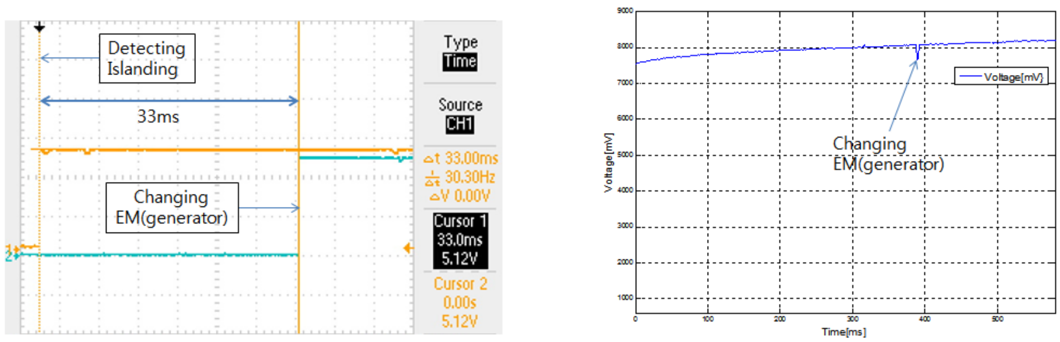

Figure 5. (a)The Detecting time of islanding and (b)EV charging voltage at occurred islanding

7. Conclusions

In this paper, we implemented micro-grid monitoring system using anti-islanding method based on wireless sensor network. The micro-grid system onsisted of a LAM and EMs. LAM was connected with EV charging system (EM) via ZigBee. The validity of this system was tested on an experimental system that simulates a micro grid. By some experimental results, it is verified that the operation of micro-grid system was performed well and the reliability of communication between a micro-grid and EVs was confirmed. The proposed RMS could be easily interconnected to smart grid system, however, future researches should improve the EV charging efficiency when using the proposed RMS and security for connecting to grid.

Acknowledgements

This research was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the ITRC (Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency) (NIPA-2012-H0301-12-2007)

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